

**A MACROECONOMETRIC POLICY MODEL OF THE SOUTH  
AFRICAN ECONOMY BASED ON WEAK RATIONAL EXPECTATIONS  
WITH AN APPLICATION TO MONETARY POLICY**

by

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## **DECLARATION**

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and has not been previously in its entirety or in part been submitted at any university for a degree.



## SUMMARY

The Lucas critique states that if expectations are not explicitly dealt with, conventional econometric models are inappropriate for policy analyses, as their coefficients are not policy invariant. The inclusion of rational expectations in conventional model building has been the most common response to this critique.

The concept of rational expectations has received several interpretations. In numerous studies, these expectations are associated with model consistent expectations in the sense that expectations and model solutions are identical. To derive a solution, these models require unique algorithms and assumptions regarding their terminal state, in particular when forward-looking expectations are present. An alternative that avoids these issues is the concept of weak rational expectations, which emphasises that expectation errors should not be systematic. Expectations are therefore formed on the basis of an underlying structure, but full knowledge of the model is not essential. The accommodation of this type of rational expectations is accomplished by means of an explicit specification of an expectations equation consistent with the macroeconometric model's broad structure. The estimation of coefficients relating to expectations is achieved through an Instrumental Variable approach.

In South Africa, monetary policy has been consistent and transparent in line with the recommendations of the De Kock Commission. This allows the modelling of the policy instrument of the South African Reserve Bank, i.e. the Bank rate, by means of a policy reaction function. Given this transparency in monetary policy, the accommodation of expectations of the Bank rate is essential in modelling the

full impact of monetary policy and in avoiding the Lucas critique. This is accomplished through weak rational expectations, based on the reaction function of the Reserve Bank. The accommodation of expectations of a policy instrument also allows the modelling of anticipated and unanticipated policies as alternative assumptions regarding the expectations process can be made during simulations.

Conventional econometric models emphasise the demand side of the economy, with equations focusing on private consumption, investment, exports and imports and possibly changes in inventories. In this study, particular emphasis in the model specification is also placed on the impact of monetary policy on government debt and debt servicing costs. Other dimensions of the model include the modelling of the money supply and balance of payments, short- and long-term interest rates, domestic prices, the exchange rate, the wage rate and employment as well as weakly rational expectations of inflation and the Bank rate.

The model has been specified and estimated by using concepts such as cointegration and Error Correction modelling. Numerous tests, including the assessment of the Root Mean Square Percentage Error, have been employed to test the adequacy of the model. Similarly, tests are carried out to ensure weak rational expectations.

Numerous simulations are carried out with the model and the results are compared to relevant alternative studies. The simulation results show that the reduction of inflation by means of only monetary policy could impose severe costs on the economy in terms of real sector volatility.



## SAMEVATTING

Die Lucas-kritiek beweer dat konvensionele ekonometriese modelle nie gebruik kan word vir beleidsontleding nie, aangesien dit nie voorsiening maak vir die verandering in verwagtings wanneer beleidsaanpassings gemaak word nie. Die insluiting van rasonale verwagtinge in konvensionele ekonometriese modelle is die mees algemene reaksie op die Lukas-kritiek.

Ten einde die praktiese insluiting van rasonale verwagtings in ekonometriese modelbou te vergemaklik, word in hierdie studie gebruik gemaak van sogenaamde “swak rasonale verwagtings”, wat slegs vereis dat verwagtingsfoute nie sistematies moet wees nie. Die beraming van die koëffisiënte van die verwagtingsveranderlikes word gedoen met behulp van die Instrumentele Veranderlikes-benadering.

Monetêre beleid in Suid-Afrika was histories konsekwent en deursigtig in ooreenstemming met die aanbevelings van die De Kock Kommissie. Die beleidsinstrument van die Suid-Afrikaanse Reserwebank, naamlik die Bankkoers, kan gevolglik gemodelleer word met behulp van ‘n beleidsreaksie-funksie. Ten einde die Lukas-kritiek te akkommodeer, moet verwagtings oor die Bankkoers egter ingesluit word wanneer die volle impak van monetêre beleid gemodelleer word. Dit word vermag met die insluiting van swak rasonale verwagtings, gebaseer op die reaksie-funksie van die Reserwebank. Sodoende kan die impak van verwagte en onverwagte beleidsaanpassings gesimuleer word.

Konvensionele ekonometriese modelle beklemtoon die vraagkant van die ekonomie, met vergelykings vir verbruik, investering, invoere, uitvoere en moontlik die verandering in voorrade. In hierdie studie word daar ook klem geplaas op die impak van monetêre beleid op staatskuld en die koste van staatsskuld. Ander aspekte wat gemodelleer word, is die geldvoorraad en betalingsbalans, korttermyn- en langtermynrentekoerse, binnelandse pryse, die wisselkoers, loonkoerse en indiensneming, asook swak rasionele verwagtings van inflasie en die Bankkoers.

Die model is gespesifiseer en beraam met behulp van ko-integrasie en die gebruik van lang-en korttermynvergelykings. Die gebruikelike toetse is uitgevoer om die toereikendheid van die model te toets.

Verskeie simulasies is uitgevoer met die model en die resultate is vergelyk met ander relevante studies. Die gevolgtrekking word gemaak dat die verlaging van inflasie deur alleenlik gebruik te maak van monetêre beleid 'n swaar las op die ekonomie kan lê in terme van volatiliteit in die reële sektor.

## **ACKNOWLEDGEMENT**

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## **CHAPTER I: INTRODUCTION**

### **1.1. PROBLEM STATEMENT AND OBJECTIVES OF THE STUDY**

Robert Lucas showed that if expectations are not explicitly dealt with, conventional econometric models are inappropriate for policy analyses, as their coefficients are not policy invariant. This finding represented a serious challenge to the usefulness of macroeconometric models for policy evaluation. It has generated various responses among the econometric profession. The most popular one has been the inclusion of rational expectations in conventional model building.

The concept of rational expectations (RATEX) has received numerous interpretations. In a large number of studies, RATEX is associated with model consistent expectations in the sense that expectations and model solutions are identical. A weaker definition emphasises that expectation errors should not be systematic. Expectations are therefore formed on the basis of an underlying structure but the full knowledge of the model is not essential.

The basic objective of this research is to build a macroeconometric model for monetary policy simulations that addresses the Lucas critique. This is accomplished by explicitly accommodating expectations in the model structure through the concept of weak RATEX, particularly for the policy instrument of the South African Reserve Bank i.e. the official interest rate of the Bank. The

introduction of RATEX upon policy instruments also introduces the issue of anticipated and unanticipated monetary policy in South Africa.

In addition to addressing the Lucas critique, RATEX represents a more refined and academically more sound expectation formation process. This should lead to superior econometric modelling and policy analyses. Rationality represents one of the basic building blocks of econometric model building as any economic relationship necessarily implies rational behaviour. Given the favourable arguments for the accommodation of expectations through RATEX, it is not surprising that an increasing number of econometric studies utilise this expectation hypothesis. Most economists consider RATEX a necessary component of any sound econometric research<sup>1</sup>. It is the intention of this study to comply with this tendency and introduce the concept of RATEX to macroeconometric model building in South Africa.

## **1.2. IMPORTANCE OF THE STUDY**

A macroeconometric model is used primarily for either forecasting or policy analyses. An aspect receiving substantial attention in econometric model building over the last decades has been the question of expectations. The Lucas critique sparked this movement and questioned the usefulness of econometric models for policy evaluation should expectations not comply with rationality.

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<sup>1</sup>. See, for example, Hall (1995).



Any model not specified in line with RATEX and upon which policy simulations are carried out is subject to severe criticism on grounds of not only the Lucas critique but also poor economic theory. In South Africa, the Reserve Bank<sup>2</sup> aims at maintaining transparency and consistency with regard to its policy. This is evident from the extensive explanations generally accommodating a change in monetary policy stance. This creates an environment where expectations regarding monetary policy are based on more than just past values of policy instruments. Economic agents in South Africa can be expected to have a fair good knowledge of the processes and variables governing monetary policy. Policy modelling and simulation have to take this feature into account in order not to fall subject to the Lucas critique and to provide an adequate representation of the nature of South Africa's economic relationships. The introduction of a specific process of expectation formation is therefore pertinent. This study addresses this issue by utilising the RATEX hypothesis. However, the application refers not only to expectations regarding policy instruments but also to all endogenous variables subject to expectation formation.

In summary, the inclusion of RATEX is argued as necessary on four grounds:

**The Lucas Critique:** Policy modelling with conventional econometric models is inappropriate as expectations concerning different policies would lead to a

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<sup>2</sup>. Stabilisation policies can be fiscal or monetary in nature. However, as in most countries, South Africa's fiscal budget allows little room for flexibility. Stabilisation has primarily been the responsibility of the South African Reserve Bank.

structural change of the model. Thus, the model upon which policies are based is not relevant any more once the policy is actually introduced.

**Theoretical Level:** RATEX represent a superior way of modelling expectations, as it is reconcilable with rationality and maximisation behaviour of individuals.

**Monetary Policy in South Africa:** The Reserve Bank follows a consistent and transparent policy, which allows its modelling by means of a policy reaction function. Expectations modelling will have to take this into account for a policy model to be relevant.

**Policy Simulations:** RATEX allow the modelling of anticipated and unanticipated policies. Such a distinction is essential whenever expectations are formed regarding monetary or fiscal policies. In South Africa, this need is enforced by the above-mentioned nature of monetary policy.

Previous South African econometric models utilised for policy simulations have not employed the concept of RATEX. This refers in particular to the modelling of monetary policy either anticipated or unanticipated (see for example De Wet, G. L., Jonkergouw, E. and Koekemoer R., 1996). Most emphasis has been given to RATEX within the New Classical framework. Examples are the evaluation of the Natural Rate Hypothesis by Shostak (1981) and Kantor and Ruskin (1982) as well as theoretical contributions by Kantor (1979), Lowenberg (1982) and Rogers (1982). Van Papendorp (1992) provides a discussion of the Lucas critique as well as an elementary application of the Error in Variable method to a small South



African model. No large scale South African policy model has yet incorporated RATEX, neither on endogenous variables nor policy instruments. Consequently, the Lucas critique applies to all existing models.

### **1.3. APPROACH AND METHOD OF INVESTIGATION**

The macroeconometric model of this study is built according to the principles of the Cowles Commission's approach, where the latter is considered as the practical approach followed by mainstream macroeconomic model builders. The definition is therefore interpreted as wide enough to incorporate concepts like cointegration and Error-Correction Models.

The model of this study will be specified on a priori economic theory. After estimation, the statistical and econometric results will be evaluated, a process that can lead to possible re-specification on statistic, economic or econometric objections. Once the model provides satisfactory results, it will undergo numerous simulations to assess the effectiveness and magnitude of monetary policy changes in South Africa.

An aspect requiring particular attention during specification and estimation is the modelling of expectations. Given that the study will focus on weak rather than strong RATEX, an explicit expectations process is specified for each variable upon which expectations are formed. This expectations process is consistent with the macroeconometric model. In this regard, the concept of cointegration will become relevant in that should the time series in question be integrated (of order

1), a necessary requirement for weak rational expectations would be a cointegrating relationship between the model's forecasts of the variable and respective expectations. This would ensure a stationary error term and therefore weak rational expectations in the sense that no systematic expectations can prevail in the long run.

RATEX will be estimated by an Instrumental Variable Technique. This equation will in the second stage serve the purpose of the expectation process. The structural model will therefore consist of conventional equations governing the determination of endogenous variables as well as structural equations determining expectations.

#### **1.4. ORGANISATION OF THE STUDY**

The study consists of three broad Sections. The first Section, consisting of Chapters II, III and IV, focuses on theoretical aspects. The Lucas critique will be illustrated as well as how the inclusion of RATEX can overcome policy invariance. The solution and estimation techniques utilised for the study will also be explained and compared with alternative approaches. Also provided is an overview of this study's model with regard to what expectation variables are considered for inclusion and how policy simulations will be carried out.

A detailed discussion and survey of the application of RATEX in large-scale macroeconometric models will be provided. Focus will fall on alternative models, solution techniques and problems. This serves the purpose of distinguishing the



approach of fully consistent RATEX models from the current approach. Numerous studies, applying an alternative and broader definition of RATEX will also be stated to identify similarities to the approach followed in this research.

Chapters V, VI and VII focus on the specification and estimation of the model. The section starts by providing a broad overview of the nature and structure of monetary policy in South Africa with regard to its goals, policy instruments and policy procedures. This is followed by a detailed discussion on the theoretical underpinnings of the econometric model. This is supported by reference to alternative macroeconometric models. The chosen estimation technique will also be addressed in this Section. Particular focus will fall on the concept of cointegration and the specification of Error-Correction Models for endogenous variables. Single equation and model properties, including the compliance of weak RATEX will also be covered.

Chapter VIII and IX represent the final Section of the study. A number of simulation results are reported in Chapter VIII and compared to simulations of alternative models. Chapter IX provides major findings of this study.

## CHAPTER II: RATIONAL EXPECTATIONS, THE LUCAS CRITIQUE AND MACROECONOMIC MODEL BUILDING

### 2.1. INTRODUCTION

During much of the 1960's, a general consensus prevailed among economists that macroeconometric models are useful and essential tools to implement Keynesian policies of active fiscal or monetary intervention. These models were used for forecasting as well as policy evaluation and were based on the Cowles Commission's methodology of specifying equations on the basis of economic theory<sup>1</sup>. However, this consensus has come under severe pressure since the early 1970's for both theoretical and empirical reasons. The empirical reason is the unsatisfactory way these models coped with rising inflation and increased unemployment. The behaviour of the industrial economies in the early 1970's were not reconcilable with Keynesian economics and consequently, the econometric models provided poor forecasts and policy results<sup>2</sup>. The theoretical criticism was spearheaded by Lucas who claimed that the empirical models were not founded on microeconomic principles such as utility maximisation (Charemza

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<sup>1</sup>. In line with Fair's interpretation (1994:4), the phrase 'Cowles Commission's approach' is used to mean *'the actual approach used by structural macro model builders, where there is much back and forth movement between specification and empirical results'* (Fair 1994:4). Given this interpretation, the phrase 'Cowles Commission's approach' and 'conventional structural modelling' are seen as synonymous in the current study.

<sup>2</sup>. Traditional econometric models used for policy evaluation are generally labelled as Keynesian models even though they may not always be based purely on Keynesian economics. This is a result of the fact that econometric modelling developed within the Keynesian tradition of active policy intervention (see Lawson (1981,1983) for an alternative comparison of Keynes' ideas and traditional econometric modelling and methodology).



1991: 47, 49). This attack was specifically aimed at the way in which these models treated expectations, namely as proxies based on no theoretical foundation. On the basis of this criticism, Lucas showed that traditional policy modelling is inappropriate as the parameters of these models are not policy independent. This conclusion is the now famous Lucas critique and represented a major obstacle to the usefulness of conventional econometric models.

The basis for the Lucas critique is the conclusion that individuals will form their expectations not on the basis of an arbitrary formula such as that implied by the adaptive expectations model but rather on all the information available. Rational Expectations (RATEX) not only form the theoretical basis for the Lucas critique of parameter instability, it also provides a solution. As will be shown in this chapter, incorporating RATEX instead of adaptive expectations into econometric modelling renders policy evaluation with econometric models appropriate again, provided certain distinctions concerning policy reactions are accommodated. Thus, the purpose of this chapter is to illustrate how traditional macroeconomic models regain their relevance and overcome the Lucas critique through the inclusion of RATEX.

The chapter is structured as follows: Section 2 addresses traditional expectations modelling in econometrics with particular emphasis on the use of the adaptive expectations hypothesis. After discussing the shortcomings of these conventional models, the Lucas critique will be discussed and illustrated. Section 3 is dedicated entirely to RATEX. After covering definitions and theoretical aspects, the emphasis will fall on explaining how RATEX addresses the Lucas critique and

what the consequences are for policy modelling. Particular emphasis is placed on distinguishing between expectations of endogenous variables and policy instruments. An evaluation will also be made of some of the criticism RATEX received in general and more specific, from the Post Keynesian School as propagated by Davidson (1982, 1987). Section 4 will round off the theoretical discussion by covering the different approaches to policy modelling with econometric models. The aim of this section is to choose the most appropriate approach in the light of RATEX and its implications. The methodology underlying econometric model building as laid down by the Cowles Commission will also be considered.

## **2.2. CONVENTIONAL EXPECTATIONS MODELLING AND THE LUCAS CRITIQUE**

Expectations play a crucial role in economic decision making, especially in the areas of macroeconomics and financial economics. In many economic relationships the variables relevant to decision making by economic units is the future value that variable is expected to take rather than its actual present value. Expectations, which are nothing but forecasts of such future values, are therefore relevant for current decisions. Consequently, the behaviour of the components of aggregate demand, such as investment, durable consumption or imports all depend on expectations of, for example, future income, interest rates or exchange rate movements.



With regard to economic modelling of expectations, the first attempts can be attributed to Friedman's permanent consumption function (1957) and Cagan's modelling of money demand in times of hyperinflation (1956) (Hoover 1992:83). However, the most popular example of the role of expectations in conventional macroeconomics is probably the Phillips curve relationship. Originally believed to reflect a stable trade-off between changes in money wage rates and unemployment, Friedman (1968) maintained that the Phillips curve is the result of workers not at first comprehending that higher money wages as a result of inflation were not also higher real wages and that they suffered from a money illusion. This resulted in the expectation augmented Phillips curve, denying, on the basis of adaptive expectation formation, any trade-off between inflation and unemployment, at least in the long run.

The traditional methodology of econometrics as laid down by the Cowles Commission is essentially one of specifying a structural model on the basis of the one or other economic theory. Given the importance the latter plays in econometric analyses, the prominent role assigned to expectations in theoretical economics must surely carry over to econometric modelling. However, the trouble with expectations is that they are subjective, personal and not easily measured for statistical analyses. Keynes, with whom economic modelling found its origin, denied even the existence of any expectation model per sé. He (1936:161-163) maintained that *'our decision to do something positive ... can only be taken as a result of animal spirits - of a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities ... human decisions affecting the future, whether*

*personal or political or economic, cannot depend on strict mathematical expectations, since the basis for making such calculations does not exist*'. And yet, to give expectations empirical meaning in econometric modelling, some form of theory that explains expectation formation is essential. Before RATEX, expectation formation was considered to be governed by the one or other formula to which individuals adhere. These are considered in the next section.

### **2.2.1. TRADITIONAL ACCOMMODATION OF EXPECTATIONS**

There are generally three ways in which expectations have been formalised prior to the appearance of RATEX, namely that of the Cobweb model, extrapolative expectations and adaptive expectations. In most econometric work, the latter has found preference and will consequently be discussed in greater detail. A short note on survey expectations will also be provided.

#### **2.2.1.1. The Cobweb Model**

The Cobweb model is an attempt to explain countercyclical movements in prices and quantities. The model incorporates static expectations, i.e. expectations of future prices are equivalent to current prices (Enders 1995 : 20)

$$x_t^e = x_{t-1}$$



Assuming inelastic and elastic demand and supply respectively, such an expectation formation will lead to a gradual convergence of demand and supply to a market clearing situation<sup>3</sup>.

A key criticism of this model is that it does not take into account that individuals will learn from their errors and will take them into account in future. As a model of expectations formation, it is thus unsatisfactory in that not only are dynamic alterations in expectations ignored but in that it also fails to define any theory underlying the formation of such expectations.

#### **2.2.1.2. Extrapolative Expectations**

In contrast to the Cobweb model, the Extrapolative Expectation model not only takes the past level of the relevant variable into account but also the direction of change (Carter and Maddock 1984: 18-20):

$$x_t^e = x_{t-1} + \varepsilon(x_{t-1} - x_{t-2})$$

where  $x_t^e$  refers to the expectation of  $x$  for and in period  $t$

and  $\varepsilon$  is the so-called coefficient of expectation

If  $\varepsilon$  is greater than zero, the past trend in the variable is expected to continue and expectations will converge to the actual value. Similarly, if  $\varepsilon$  is smaller than 1, the

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<sup>3</sup>. For an extensive discussion on the Cobweb model and its properties, see Pesaran (1987:36-42) or Enders (1995: 20-25).

past trend is expected to weaken. If  $\varepsilon$  equals zero, extrapolative expectations are reduced to the Cobweb Model.

Similar to the Cobweb Model, expectation errors are not considered in the Extrapolative Expectations Model. Consequently any rational learning is denied. In addition, although the last term takes the current trend into account, the Extrapolative Expectation Model is unable to accommodate any change in the trend (parameter  $\varepsilon$  is a constant). Anticipation of any alterations in the trend is therefore not possible.

#### **2.2.1.3. Adaptive Expectations**

In contrast to the above expectation formule, adaptive expectations represent a dynamic model specification in that it provides for some learning by individuals. However, as outlined in the critique, this learning process is very limited and not necessarily reconcilable with rational behaviour.

The adaptive expectations hypothesis postulates that a forecast formed in period  $t$  equals the forecast of the previous period, revised by an amount proportional to the last forecasting error (Pindyck and Rubinfeld 1991: 206-208)

$$x_t^e = x_{t-1}^e + \alpha(x_{t-1} - x_{t-1}^e)$$

or



$$x_t^e = \alpha x_{t-1} + (1 - \alpha)x_{t-1}^e \quad (1)$$

where  $0 < \alpha < 1$

Equation (1) shows that individuals use information on past forecasting errors to revise current expectations. This simple expectation formation mechanism is usually referred to as a first order adaptive scheme or a first order error correction model as was initially applied by Koyck (1954), Cagan (1956) and Nerlove (1958) as referred to by Pesaran (1987:17). Equation (1) can easily be generalised to higher order schemes, allowing the  $r^{\text{th}}$  order Adaptive Expectation model to be written as:

$$x_t^e = x_{t-1}^e + \sum_{i=1}^r \alpha_i (x_{t-i} - x_{t-1}^e)$$

The attractiveness of the Adaptive Expectation model (equation (1)) is that it allows unobservable expectations to be modelled in terms of past values without specifying the process by which the initial expectations are formed (Begg 1982:23). Adaptive expectations are simply a weighted average of past values whose weights decline geometrically, given the assumption governing the parameter and recursive substitution:

$$x_t^e = \sum_{i=1}^{\infty} (1 - \alpha_i) x_{t-i-1}$$

A common criticism of adaptive expectations is that they are entirely backward looking. As can be seen from equation (1), individuals only consider past values and error forecasts in their expectation formation. This has the implication that systematic forecasting errors are possible period after period without requiring any amendment to the basis of the forecasting rule itself (Begg 1982:29). Consequently, such an expectation model is unsatisfactory in that it implies partial irrationality of individuals as they are ignorant not only about the actual process determining the expected variable but also about additional information. The rationality assumption requires that individuals consider all information, including announced policy changes, rather than obeying an expectations formula. Consequently, adaptive expectations represent a violation of the rationality assumption governing economic relationships and has to be seen as nothing more than an econometric attempt to approximate expectations by data projection rather than a behavioural expectation model actually governing rational individual's expectation responses. Muth (1961:315), the founder of the RATEST concept, states it as follows: *'To make dynamic models complete, various expectations formulas have been used. There is, however, little evidence to suggest that the presumed relations bear a resemblance to the way the economy works'*.

The second major critique is also linked to the rationality violation. If a static equilibrium exists, an individual forming adaptive expectations will eventually correctly anticipate the expected value. According to Begg (1982:24), this is a



minimal requirement for a plausible rule for modelling expectation formation. However, in the case of a non-static equilibrium, where trends themselves are subject to change, adaptive expectations may never coincide with the actual value. For example, in periods of accelerating inflation, adaptive expectations will systematically underestimate the actual rate of inflation (Pesaran 1987:18-19). This problem results from the assumption of only partial adjustment of past errors (assumptions of parameter  $\alpha$ ) and the failure to take additional information into account. As indicated, such an expectation model cannot be reconciled with rational decision making. However, Cuthbertson and Taylor (1987:120-122) mention one case where adaptive expectations can be considered as optimal. That is the case when the variable in question follows an integrated moving average one-one process:

$$y_t = y_{t-1} + \pi_0 e_t + \pi_1 e_{t-1}$$

where  $e_t$  and  $e_{t-1}$  are white noise error terms

In this case, the optimality of adaptive expectations originates from the common process the expectations and the actual variable share in their determination. However, within the context of adaptive expectations this is purely a coincidence as the actual process governing the variable happens to coincide with the adaptive expectations formula if expectations are taken<sup>4</sup>. Criticism that the foundation for

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<sup>4</sup>. Using  $L$  as a lag operator ( $L(e_t) = e_{t-1}$ ), the process can be written as follows:

$y_t - y_{t-1} = (H_0 + H_1 L)e_t$  or  $y_{t-1} - y_{t-2} = (H_0 + H_1 L)e_{t-1}$  thus  $e_{t-1} = (y_{t-1} - y_{t-2}) / (H_0 + H_1 L)$  Given  $e_t^e = 0$ ,  $y_t^e = y_{t-1} + H_1 e_{t-1}$  which leads to the following expression:  $y_t^e - y_{t-1} = H_1 [(y_{t-1} - y_{t-2}) / (H_0 + H_1 L)]$  Rearranging this equation results in:  $H_0 y_t^e + H_1 y_{t-1}^e - H_0 y_{t-1} - H_1 y_{t-2} = H_1 y_{t-1} - H_1 y_{t-2}$ . Simplifying

such a process in terms of economic theory is not specified and that any changes in that process would again result in sub-optimal expectation formation is however still appropriate. Therefore, the key critique of adaptive expectations is that in its expectation specification, it fails to take account of the actual process governing economic variables as outlined by economic theory and evidence. This will be discussed explicitly in the discussion of the Lucas Critique below.

#### **2.2.1.4. Survey Expectations**

All of the above approaches have attempted to model an expectation process to derive values for expectations. An alternative way of deriving expectations values is by using survey data.

Increased attention has been given to the question of whether survey data of expectations are rational. For example, Bakhshi & Yates (1998) conclude that UK inflation expectations are not rational for the period 1984 - 1996 but that expectations systematically overstate actual inflation. Alternatively, Kim (1997) concludes that survey expectations on the exchange rate and interest rates for Australia are at best weakly rational in the sense that all relevant information has been taken into account but expectations are not unbiased predictors of actual future variables. Finally, Ilmakunnas (1989) compared survey expectations with rational expectations in a model explaining the demand for labour in Finnish

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this result further:  $y_t^e - y_{t-1} = (H_1/H_0)(y_{t-1} - y_{t-1}^e)$  or  $y_t^e = y_{t-1} + (H_1/H_0)(y_{t-1} - y_{t-1}^e)$ , which is nothing but the Adaptive Expectations Model.



manufacturing. He (1989:312) concluded that survey data provided more realistic estimation results than rational expectations. For a comprehensive survey of tests of rational expectations in survey data, see Zimmermann (1997) (as referred to by Bakhshi & Yates: 1998:7).

From the perspective of policy simulations, the use of survey expectations is limited unless the survey expectations become receptive to policy changes and thus endogenous to the policy model.

### **2.2.2. THE LUCAS CRITIQUE**

Publishing in the Journal of Monetary Economics in 1976, Robert Lucas questioned the usefulness of the conventional approach to policy evaluation through econometric models. This paper is widely seen as the most formidable challenge ever made to the legitimacy of econometrics applied to macroeconomics (Hoover 1988:192). Lucas casts serious doubts on the important assumption that structural relationships are invariant with respect to alternative policy decisions. Optimising behaviour of economic agents depend on expectations of, among other things, policy rules and their implications. However, conventional proxies for expectations fail to take account of the fact that policy interventions may change expectations. Consequently, any such change will alter the expectations partly determining the structural behaviour of the economy. The structure of policy models varies therefore systematically with the choice of policy. (Farmer 1991:321 and Chung 1986:140-141). In Lucas' (1976:41) own words: '*...Given that the structure of an econometric model consists of optimal decision rules for*

*economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models... .’*

The Lucas Critique, if empirically important, is rather devastating (Cuthbertson and Taylor 1987:109). This can be seen from the way in which existing econometric models are used. Empirical macroeconomists specify and estimate a model. Given estimated coefficients, the model is simulated under current and hypothetical policies and the different behaviour of policy targets considered as the consequences of the alternative policies. A key assumption in this traditional approach is the policy neutrality of the coefficients i.e. no policy change will have any affect on the estimated relationships. This is essential for there to be any adequate policy forecasts. However, according to the Lucas Critique any change in the policy rule (or other exogenous factors) alters the estimated parameters of the reduced form response by altering expectations of agents whose behaviour is summarised by the reduced form model. This led Lucas (1976:41) to conclude that *‘comparisons of the effects of alternative policy rules using current macroeconomic models are invalid regardless of the performance of these models over the sample period’*.

To illustrate the Lucas critique, the following simple two equation model with one expectations variable is considered (error terms are ignored):

$$y_t = \beta_0 + \beta_1 n_t + \beta_2 x_t^e$$



$$n_t = \tau_o + \tau_1 n_{t-1}$$

where  $y_t$  and  $n_t$  are endogenous variables and  $x_t^e$  the expected value of  $x_t$ .

Assuming adaptive expectations, the equation concerning  $y_t$  can be rewritten as

$$y_t = \beta_o + \beta_1 n_t + \beta_2 \left[ \sum_{i=0}^{\infty} (1-\alpha) x_{t-i-1} \right] \quad (2)$$

Applying a Koyck transformation<sup>5</sup>, equation (2) can be written as:

$$y_t = -\beta_o \alpha - (1-\alpha) y_{t-1} - \beta_1 (1-\alpha) n_{t-1} + \beta_1 n_t + \beta_2 x_{t-1}$$

or

$$y_t = -\beta_o^* - \beta_1^* y_{t-1} + \beta_2^* n_{t-1} + \beta_1 n_t + \beta_2 x_{t-1}$$

This leads to the following reduced form model:

$$y_t = (\beta_o^* + \beta_1 \tau_o) + \beta_1^* y_{t-1} + (\beta_2^* + \beta_1 \tau_1) n_{t-1} + \beta_2 x_{t-1} \quad (3)$$

$$n_t = \tau_o + \tau_1 n_{t-1} \quad (4)$$

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<sup>5</sup>. A Koyck transformation involves taking the equation of  $y_{t-1}$ , multiplying it with  $(1-\alpha)$  and then subtracting it from equation (2). In this fashion, the infinite lag structure of variable  $x$  imposed by Adaptive Expectations is eliminated, resulting in a further lagged dependent (dynamic) term. For a detailed description, see Pindyck & Rubinfeld (1991:204-210) or Koutsoyiannis (1977).



Equations (3) or (4) are in a more convenient form than equation (2), resulting in possible estimation of structural or reduced form parameters. Most of these parameters are however, functions of  $\alpha$  and it is this fact that gives rise to the Lucas Critique. Any change in this parameter and hence in the way expectations are formed, will alter the estimated parameters of the reduced and structural model. As an example, assume that  $x_t$  represents the expected inflation rate and that the Central Bank announces a more lenient attitude towards money supply growth. This announcement will have two effects:

Firstly, individuals will alter their expectations in that this new information will be incorporated into the expectation formation process. This, in turn, implies that past expectations and their error terms are of less importance, given the new and more relevant information regarding monetary policy. Thus, **parameter  $\alpha$  in the Adaptive Expectation formula will become smaller or even quantitatively insignificant**, resulting in an alteration of all estimated parameters.

The second consequence affects the specification of the structural equations and in that regard will affect all structural parameters. The announcement of the monetary authorities will result in a behavioural change in that this **announcement becomes a variable in the structural equations**. This could be for only a particular period, representing a temporary structural instability or expectations of monetary policy could become a permanent aspect of individuals when forming expectations of the inflation rate and in that regard lead to a permanent alteration of the structural equations (the equation of variable  $y$  in this case).



It should be trivial to point out that in both of the above cases, the specified model would be inappropriate for policy modelling. As soon as the policy is announced or implemented, the econometric model becomes inappropriate and consequently, it is impossible to evaluate any policy with such a model. This is true whether the variable in question is endogenous or even a policy instrument. In the latter case, alteration in monetary policy would again change the adaptive expectations formula in that past expectation errors become inappropriate to evaluate, given the new environment and information.

The previous discussion has shown that the Lucas critique originates from the way in which expectations have been accommodated through the application of adaptive expectations. In this regard, Hoover (1988:191-192) maintains that the Lucas critique is related to the identification problem in econometric model building in that the observed relationships are a combination or outcome of observable and unobservable variables. Consequently, deriving conclusions solely from observable data is inappropriate as the nature of these relationships is a function of expectations as outlined in the above example. The Lucas critique thus refers to inadequate model specification whereas the term inadequate refers to the specification of expectation formation: *'Although Lucas was not the first to recognise the invariance problem explicitly, his own important contribution to it is to observe that one of the relations frequently omitted from putative causal representation is that of the formation of expectations'* (Hoover 1988 : 191-192). Similarly, Favero and Hendry (1992:266) maintain that *'if correct ... [the Lucas critique] is a damaging criticism of any econometric research which does not*



*separately model the expectations formation of economic agents and their behavioural plans, since confounding the two will lead to predictive failure when the stochastic processes of the determining series alter* '. It is precisely this aspect that RATEX, as a theory focusing on the process governing expectations, addresses.

### **2.2.3. REACTIONS TO THE LUCAS CRITIQUE**

The Lucas critique represents the most formidable critique of the use of macroeconometric models as a guide to economic policy (Bodkin, Klein and Marwah 1991:552). Lucas and Sargent (1981:316) conclude that '*the existing Keynesian macroeconomic models cannot provide reliable guidance in the formulation of monetary, fiscal or other types of policies ... there is no hope that minor or even major modification of these models will lead to significant improvement in their reliability*'.

This conclusion has led to three broad responses. Firstly, some econometricians have perceived the Lucas critique as theoretically valuable but of little practical importance (see Bodkin et al. 1991:552-553). The justification for this conclusion rests on the presumption that individuals do not possess adequate information when forming their expectations and hence only rely on a formula of historic events. However, such an argument could imply irrational behaviour, as it is unrealistic to expect that when a policy authority announces a new approach, individuals will be ignorant enough to ignore the resulting implications and adhere to their adaptive formula. Equally unrealistic is the view that individuals will



continuously make mistakes without learning from them. Therefore, simply ignoring the Lucas critique in policy modelling appears unsatisfactory.

The second response has been the complete abolition of structural econometric modelling, an approach associated with Sim's (1981) work on vector autoregression models (VAR models). Although further discussed below, it needs to be stated that these models deny any structural evaluation and are primarily aimed at forecasting. Consequently, for policy modelling, this approach is inferior to macroeconometric modelling as supported by Hall (1995:975): *'Structural macroeconometric modelling still remains the most promising approach to understanding macroeconomic behaviour generally and is the most likely approach to provide a really powerful policy tool'*.

The third approach counters Lucas and Sargent's conclusion by explicitly focusing on the incorporation of RATEX into traditional, structural modelling. As outlined in the next section, this provides not only an answer to the Lucas critique, it places expectations modelling on an equal foundation with structural model specification. It is this approach that will be used in the study as it allows the accommodation of the Lucas critique within structural macroeconometric modelling.

### **2.3. THE THEORY OF RATIONAL EXPECTATIONS**

Structural econometric modelling involves the specification and quantification of economic relationships where these relationships are based on the assumption of rational behaviour. RATEX represents a logical extension of this line of reasoning

to the sphere of expectations formation. Consequently, RATEX are expectations formed under the full utilisation of the available information. Thus, expectations are not formed on the basis of the one or other formula but rather on the basis of the process actually determining the variables.

### **2.3.1. DEFINITIONAL ASPECTS**

#### **2.3.1.1. The Concept of RATEX and its Characteristics**

Writers such as Marshall (1923) and even Keynes (1930) (as referred to by McDonald 1987:266) have suggested that rational economic agents may form expectations by utilising an information set extending beyond the past history of the relevant variable. However, it was left to Muth (1961) to formalise the RATEX concept. Muth noticed that dynamic economic models use expectations of variables as inputs and at the same time generate predictions of those same variables. If the model is correct and people use it to make predictions, then consistency should dictate that people should expect precisely what the model tells them will occur. For Muth, rational expectations are such expectations. *‘In order to explain fairly simply how expectations are formed, we advance the hypothesis that they are essentially the same as the predictions of the relevant economic theory ... I should like to suggest that expectations, since they are informed predictions of future events are essentially the same as the predictions of the relevant economic theory ’* (Muth 1961:315,317). Formally, RATEX can be defined as follows:



If  $\Pi_{t-1}$  is the available information in period  $t-1$ , then:

$$E(x_t / \Pi_{t-1}) = \beta \Pi_{t-1} \quad (5)$$

resulting, under the assumption of linear relationships, from the equation

$$x_t = \beta \Pi_{t-1} + e_t$$

where  $e_t$  is a white noise process.

Equation (5) implies that individuals consider all available information when forming their expectation. However, the selection of the elements of vector  $\beta$  is determined by the underlying economic structure so that not all variables of  $\Pi$  will necessarily be relevant.

As a result of the incorporation of all available information into expectation formation, expectation errors will be uncorrelated with past values of all relevant variables (including the error variable itself). This condition is necessary to avoid the implication that there exists unexploited opportunities for economic gain in that not all information has been used<sup>6</sup>.

According to Cuthbertson and Taylor (1987:84-89), RATEX have the following relationship with the ex post realised values:

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<sup>6</sup>. The underlying assumption of this conclusion is that the marginal gain from additional information exceeds its marginal cost of acquisition. This aspect will again be addressed below.



- Unbiasedness:*** On average, expectations are correct.  
(This follows from the assumed white noise error term).
- Orthogonality:*** All relevant information and not just lagged own values is considered. The error term is therefore independent (orthogonal) to the information set. (This is essential to justify the rationality assumption).
- Consistency:*** Information available is used in a logically consistent manner.  
(If the error term is white noise, the individual will continue to rely on the same processes governing RATEX. Only relevant new information will alter this process).

According to Muth (1981:5), RATEX further implies that :

- Information is scarce and economic participants do not waste it.
- The way in which expectations are formed depends specifically on the relevant structure describing the economy.
- A public prediction will have no substantial effect on the operation of the economic system.

The type of information agents require to form RATEX include (Mullineux and Thompson 1982:49) :

- Past observations plus future values of certain time series.  
(If future expectations are involved, future values of exogenous or endogenous variables have to be known)
- The correct functional form of all structural equations of the model including the government's reaction function (this is usually believed to be linear or log linear)
- Coefficients for the variables contained in the various equations (the reduced form estimated parameters).

#### **2.3.1.2. Weak Versus Strong RATEST**

Mullineux and Thomspon (1982:48) argue that *It is worth emphasising that the idea of rational expectations was developed in the context of a single demand and supply model in which the supply curve depends on expected prices. In that case, it is not unreasonable to assume that the suppliers in the market have sufficient knowledge of how the market operates to form expectations according to the relevant structure describing the economy. It is not so apparent that agents have the same detailed information about the complex macro-structure of an economy.*

If the three information requirements are interpreted as implying knowledge on exogenous variables as well as functional forms and values of coefficients of single equations or subset of equations of a model, RATEST can be introduced into conventional model building rather straightforwardly. However, such RATEST will have to be classified as weakly rational as full knowledge of the model is not necessary and as a result, fully model consistent expectations are not formed.



Colander and Guthrie (1980:222) make the useful distinction between strong and weak RATEST. The central characteristic of strong RATEST is that the relevant model describes the objective reality. Thus, the true model of the economy is known to the economic agents. This is the version defined by Muth as outlined above. According to Gerrard (1994:329), strong RATEST involve three assumptions viz.:

- Agents have complete information of the economic structure
- The probability distribution governing the stochastic component of the economic structure is well defined and known.
- There is certainty equivalence in that less than perfect foresight implies that known future values are replaced by their expected values.

It appears that the strong version of RATEST is rather unrealistic in a world of imperfect knowledge and competing economic theories, a statement supported by Handa (1982:559, 563), who maintains that the strong version represents nothing but a '*stochastic mask on the inquiry to conceal the perfect foresight hypothesis*'. Indeed, as maintained by Gerrard (1994:329-330), Keynesian criticism of RATEST should be seen not as a rejection of the rational expectation hypothesis per se but rather as the rejection of the unrealistic context of application of RATEST as implied by the first two assumptions.

The way in which Colander and Guthrie (1980:222) define the weak concept of RATEST renders this version much more realistic. Weak RATEST assume that the

model upon which expectations are formed may not be correct and further that the choice of model is also stochastic whereas in the strong case, only the model's predictions are stochastic as the actual model is assumed to be known<sup>7</sup>. All that the weak version requires is that individuals use all available information in forming their expectations. This is nothing more than applying the rationality assumption so central in economics to the theory of expectations formation. This, in essence, is what Muth (1981:4) implied when defining RATEX: *'It is sometimes argued that the assumption of rationality in economics leads to theories inconsistent with, or inadequate to explain, observed phenomena, especially changes over time.... Our hypothesis is based on exactly the opposite point of view: that dynamic economic models do not assume enough rationality'*. Hence, whether strong or weak RATEX, both versions can be reconciled with Muth's original line of thought.

As Colander and Guthrie (1980:222) state, in normal economic modelling, the distinction between the weak and strong form of RATEX is of little importance as the models are designed as if they were the true description of the economic system. However, once the emphasis falls on the evaluation of different policy options, the distinction is of importance as assumptions have to be made regarding the expectations economic agents form of the processes governing the policy instruments (this will be discussed in greater detail in Section 1.3.2 below).

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<sup>7</sup>. Flemming, as referred to by Mullineux and Thompson (1982:50) defines weakly rational expectations as being economically rational in that information to form expectation is only increased if there is a net benefit. Thus, weak rational expectations are not fully model consistent expectations. For a further definition of weak and strong RATEX, see Swamy, Barth and Tinsley (1982).



**Throughout this study the weak version of RATEX will apply.** This is primarily based on the questionable assumptions and information requirements of the strong version. The application of weak RATEX also avoids the utilisation of a solution technique that can be questioned on numerous grounds as spelled out in Chapters III and IV.

### **2.3.2. HOW DOES RATEX ADDRESS THE LUCAS CRITIQUE?**

It was argued above that the coefficients of an adaptive expectations model are not policy invariant in that the coefficient in the adaptive expectations formula (parameter) will change when policy rules change. Providing for RATEX, on the other hand, would make the parameters of such expectations variables policy-invariant in that the process determining the expectations are consistent with the overall model. The process determining the expectations is structurally stable in that it is based on the actual process determining the variables. To illustrate how RATEX can be used to address the Lucas critique, it is essential to differentiate between expectations with respect to policy instruments and those made about endogenous variables.

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### 2.3.2.1. Endogenous Variables

Consider the extended version of the above model:

$$y_t = \beta_0 + \beta_1 n_t + \beta_2 x_t^e$$

$$x_t = \gamma_0 + \gamma_1 x_{t-1} + \gamma_2 y_t^e$$

$$n_t = \tau_0 + \tau_1 n_{t-1}$$

where  $y_t$ ,  $x_t$ , and  $n_t$  are endogenous variables and  $y_t^e$ ,  $x_t^e$ , and  $n_t^e$  represent the respective expectations of the variables for and in period  $t$  (current expectations<sup>8</sup>).

Taking conditional (subject to the model) expectations:

$$E(y_t) = E(\beta_0) + E(\beta_1 n_t) + E(\beta_2 x_t^e)$$

$$E(x_t) = E(\gamma_0) + E(\gamma_1 x_{t-1}) + E(\gamma_2 y_t^e)$$

$$E(n_t) = E(\tau_0) + E(\tau_1 n_{t-1})$$

Given that  $x_{t-1}^e = x_{t-1}$  and  $n_{t-1}^e = n_{t-1}$ :

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<sup>8</sup>. An aspect requiring unique attention in modelling and solving RATEX models is the question of future expectations. This will be discussed in detail in Chapter III. For the purpose of illustrating the Lucas critique, only current expectations are considered as it simplifies the discussion and consequently highlights the argument being made.



$$y_t^e = \beta_0 + \beta_1 n_t^e + \beta_2 x_t^e$$

$$x_t^e = \gamma_0 + \gamma_1 x_t^e + \gamma_2 y_t^e$$

Solving for the expectations variables results in:

$$y_t^e = \lambda [(\beta_0 + \beta_1 \tau_0 \beta_2 \gamma_0) + (\beta_1 \tau_1) n_{t-1} + (\beta_2 \gamma_1) x_{t-1}] \quad (6)$$

$$x_t^e = \lambda [(\gamma_0 + \gamma_2 \beta_1 \tau_0 + \gamma_2 \beta_0) \gamma_1 x_{t-1} + (\gamma_2 \beta_1 \tau_1) n_{t-1}] \quad (7)$$

where 
$$\lambda = \frac{1}{(1 - \beta_2 \gamma_2)}$$

From equations (6) and (7) it follows that RATEX can be expressed as linear combinations of the predictions of the exogenous variables or predetermined variables. Thus, the information requirement to form RATEX comprises only of knowledge concerning past or exogenous variables. Although this appears to be similar to adaptive expectations, RATEX differ in that the economic structure, as reflected by these equations, is the basis for expectation formation.

Substituting these equations into the original model results in the following reduced form model

$$y_t = (\beta_0 + \beta_1 \tau_0 + \beta_2 \lambda \gamma_0 \beta_2 \lambda \gamma_2 \beta_1 \tau_0 + \beta_2 \lambda \gamma_2 \beta_0) + (\beta_1 \tau_1) n_{t-1} + (\beta_2 \lambda \gamma_1) x_{t-1} + (\beta_2 \lambda \gamma_2 \beta_1 \tau_1) n_{t-1}$$

$$x_t = (\gamma_0 + \gamma_2 \lambda \beta_0 + \gamma_2 \lambda \beta_1 \tau_0 + \gamma_2 \lambda \beta_2 \gamma_0) + (\gamma_2 \lambda \beta_2 \gamma_1 + \gamma_1) x_{t-1} + (\gamma_2 \lambda \beta_1 \tau_1) n_{t-1}$$

$$n_t = \tau_0 + \tau_1 n_{t-1}$$

Given that all variables are measurable, the coefficients of the above model can be estimated with conventional estimation techniques. As can be seen from equations (6) and (7), the structural equation governing a variable is the foundation upon which expectations are based. Consequently, the expectations formation process will not alter as long as the model is not changed. Policy modelling is therefore possible with the reduced form of the model as the parameters are policy invariant. The reduced form parameters are functions solely of the structural equation's parameters ( $\lambda$  is a function of structural parameters) and not of expectation parameters such as in the case of adaptive expectations. Thus, a solution is found for the Lucas critique with regard to endogenous variables.

### 2.3.2.2. Policy Instruments

With regard to expectations of policy instruments, the problem is more difficult in that a policy change, as indicated above, necessarily implies a change in the structural process (policy rule) determining the policy instrument. Thus, incorporating RATEX will not eradicate structural instability in this respect, on



the contrary, it will make it explicit. Thus, RATEX introduces structural instability rather than provides a solution. However, incorporating it into a model allows an explanation as to how the model will change in response to policy alterations. In that regard, RATEX forces the econometrician ‘*to specify whether a given movement in a policy variable was foreseen beforehand or unforeseen, an old and important distinction in economics, but one that makes no difference in the usual evaluation of policy made with [traditional] macroeconomic models*’ (Sargent and Wallace 1981:210). Thus, incorporating RATEX forces the policy analyst to specify the assumptions concerning policy reactions and in particular whether:

1. ***Interventionist policy is in line with past policy and is therefore consistent with RATEX***
2. ***Discretionary policies are not in line with past policies and hence are not anticipated through RATEX***
3. ***Continuous deviations from a specified policy rule or the introduction of a new policy will necessarily lead to an adjustment in RATEX***

These aspects can be seen as being part of the RATEX logic in that any policy can be divided into a systematic component and a random component where case 1 and 2 represent the two border cases of systematic and random policies respectively (Hoover 1992:85). Case 3 is the outcome of a combination of the two components. Similarly, anticipated and unanticipated policies fall under case 1 and

2 respectively with case 3 again representing a dynamic adjustment process caused by consecutive occurrences of case 2.

The three cases will have to be accommodated in any stabilisation policy to address the Lucas critique and it is RATEX (in its weak form) that provides the rationale for such a distinction and how to address it. RATEX does therefore not solve the Lucas critique with regard to policy instruments as is the case with endogenous variables but rather provides a framework for its proper accommodation.

As will become apparent in the survey of existing RATEX models below, the accommodation of expectations formation regarding policy variables has not been explicitly dealt with, a feature largely based on the type of solution technique employed in these models.

### **2.3.3. FURTHER REASONS FOR THE INCLUSION OF RATEX**

Besides the Lucas critique, Sargent and Wallace (1981:209-210) mention various other reasons why RATEX should be included in an econometric policy model. As already mentioned, the RATEX hypothesis is in line with the usual practice of assuming that people are rational and act in their best own interest as it implies full utilisation of available information. Consequently, irrational ignorance, as implicitly incorporated in the adaptive expectations hypothesis, is eliminated. Mankiw (1988:440) sums it up rather strongly by maintaining that *'economists routinely assume that firms rationally maximise profits and that consumers*



*rationally maximise utility. It would be an act of schizophrenia not to assume that economic agents act rationally when they form their expectations of the future '.*

A further aspect of RATEX is that they are reconcilable with the models' structure or forecast. In contrast to the adaptive expectations model, where expectations are believed to be determined by a formula without ever considering as to why individuals should follow this rule, reasons can be given for why individuals form RATEX, namely the desire to derive optimal economic decisions. Just as equation specification is subject to economic theory and reasoning, processes determining expectations should be evaluated in a similar fashion. Building a stabilisation model on economic reasoning and rationality necessitates therefore the inclusion of RATEX. Thus, the latter represents a more refined way of representing expectations and not just a way of accommodating the Lucas critique.

Finally RATEX helps to address the identification problem as no lag structures have to be specified for expectations formation. Lucas and Sargent (1981:301) maintain in this regard that '*structural equations are usually identified by the assumption that the expectation ... [of] agents is a function only of a few lagged values...*'. These restrictions are not only in contradiction to the hypothesis of self interest as already outlined, they '*are entirely arbitrary and have not been derived from any deeper assumption reflecting first principles about economic behaviour*'. This refers to the above mentioned argument that RATEX extends the common practice of equation specification to expectation formation. Thus, besides the Lucas critique, the most prominent argument for the utilisation of RATEX lies in *the failure of existing models to derive restrictions on expectations from any first*



*principles grounded in economic theory [which] is a symptom of a deeper and more general failure to derive behavioural relationships from any consistently posed dynamic optimisation problems ' (Lucas and Sargent 1981:302).*

#### **2.3.4. RATEX VERSUS THE POLICY INEFFECTIVENESS PROPOSITION**

An issue closely related to expectations of policy variables is that of the policy inefficiency proposition which states that any policy will have no real effects as individuals will anticipate such a policy given RATEX. However, this conclusion relies strongly on additional assumptions of the New Classical Model. Unfortunately, early publications have regarded the concept of RATEX and the New Classical Model as interchangeable terms, a misperception strongly contributing to the statement that RATEX implies policy ineffectiveness<sup>9</sup>.

The New Classical Model rests on the assumptions of perfect price flexibility and the natural rate hypothesis, resulting in vertical Phillips and supply curves. Where RATEX comes in is in the time dimension of these vertical curves in that, as Mullineux and Thompson (1982:58) point out, RATEX reduce the scope for stabilisation policy by shortening the time lag between policy change and reaction of the private sector. Thus, short term vertical Phillips and supply curves become feasible under RATEX.

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<sup>9</sup>. Although Muth formally introduced RATEX, it was the New Classical economists like Lucas and Sargent that introduced it to mainstream macroeconomics by incorporating it into their models. This could be the reason for the misperception.



Mankiw (1988:440,441) sums it up when stating that *'By itself, the assumption of rational expectations has no empirical implication .... Yet together with other auxiliary hypothesis, ... the assumption can have profound and startling implications.... Policy irrelevance was sometimes said to be the implication of rational expectations per se. We now know that rational expectations is not the issue at all'*. Thus, it is the combination of RATEX and the assumption of immediate market clearing, the natural rate hypothesis and symmetric information distribution upon which the ineffectiveness proposition stands. Indeed, as Hoover (1992:86) points out, it has primarily been the natural rate hypothesis and not RATEX upon which most attacks against the ineffectiveness proposition were build.

### **2.3.5. CRITIQUES OF RATEX**

The differentiation between weak and strong RATEX requires the separation of criticism into two broad categories. The first one, referred to below as general critique, can be considered as the conventional line of criticism primarily associated with the strong form of RATEX. However, the second form of criticism, which originates with Davidson's (1982, 1987) argument of a nonergodic world, is of a more severe nature as it could have far reaching implications for expectations modelling in general.

### 2.3.5.1. General Critique

The basic tenet of RATEX, that individuals do not just extrapolate from the historical record and that individuals do respond to policy statements is generally conceded. The reconciliation of RATEX with the basic principles of maximising behaviour also makes it difficult to criticise the doctrine on theoretical ground. So what is the general critique? Firstly, it is the argument centering around information. Critics proclaim that individuals simply do not possess adequate information and the skills to process it to the extent that RATEX would require. According to Bodkin et al. (1991:553), *'...it is difficult to imagine a typical citizen, untrained in macroeconomics, [to come] to the same specific conclusions as a professional economist on an issue of macroeconomic policy, let alone following the same specific steps in the reasoning process'*. Furthermore, accepting utility maximisation, it is not at all clear why individuals would consider such an act in the light of the cost involved with information acquisition. This line of reasoning is a general missperception of what is meant by RATEX. As Shaw (1984:47-48) maintains : *' [RATEX] need not imply that individuals will utilise all possible relevant information .... Instead what is being asserted is that individuals will acquire and process information ... as long as perceived marginal benefits ... exceed marginal costs '*. Hence, the assumption of uncorrelated error terms are not a prerequisite to RATEX if the costs of acquiring additional information from the error terms exceed the additional benefits. This is a rather unfamiliar conclusion when the general definition and meaning of RATEX is considered. This aspect is addressed again below when referring to the concept of cointegration.



The entire discussion of marginal optimisation as discussed above appears to be inappropriate. An individual will not be able to evaluate the benefits of additional information unless he acquires that information in the first place. It is much more feasible to maintain that individuals will acquire additional information on their ex ante perception of the possible costs associated with a false expectation rather than on the evaluation of the marginal costs and benefits of additional information. Costs should always be associated with the entire potential losses involved in false expectations and given that potential benefits of additional information are not known, a rational individual will be inclined to acquire information up to the point where the marginal costs of additional information and the entire potential costs of false expectations are equalised. Thus, the amount of information an individual accumulates in his expectation formation depends on the weight he associates with the decision he is taking and not the marginal benefit of information. This conclusion is in line with utility maximisation and is reconcilable with RATEX.

Given that individuals do not possess all information, it is incorrect to maintain that RATEX will always be correct. As stated above in the context of weak RATEX, the true model governing a variable may differ from the process governing expectations. Weak RATEX provide therefore an answer to a further common critique centering around the existence of and knowledge about the true model. However, Gerrard (1994:330) maintains that *'once incomplete information sets and ill-defined probability distributions are allowed [thus weak RATEX], there is an infinite range of possible special cases and the modeller is well and truly ... on a slippery slope'*. Referring to Lucas, he (1994:330) maintains that *'the rational expectations hypothesis is most useful in situations in which probabilities*

*relate to well defined recurrent events .... Lucas views rational expectations as an equilibrium concept, relevant to steady state outcomes of adaptive processes in which agents have acquired full information of the objective probability distribution*'. Consequently, only strong RATEX are believed to be appropriate. This appears to represent a devastating critique to weak RATEX, making it inappropriate for modelling purposes. However, the context within which weak RATEX are introduced in this study has to be emphasised. An infinite range of possible special cases is avoided by assuming and specifying three possible policy reactions as outlined in Section 3.2 above. The modeller is therefore not faced with infinite possibilities of weak RATEX, on the contrary, as indicated, weak RATEX provides the framework within which the three policy alternatives can be evaluated. It is the weak form of RATEX that allows the accommodation of alternative expectations regarding the policy instrument.

A critique closely related to the one above is the argument that individuals will never be able to know the true model as it is constantly subject to structural change. This is one aspect of Davidson's (1981) critique which will now be attended to.



### **2.3.5.2. Davidson's Critique of the RATEX hypothesis**

#### **2.3.5.2.1. *Nonergodicity and Stable Economic Relationships***

Standard Post Keynesian arguments against RATEX all concern the barrenness of knowledge on which to base a rational forward-looking decision (Rutherford 1984: 383). For Davidson (1981), the origin of this information insufficiency lies in the simple conclusion that the world is nonergodic. The latter refers to a state where history and current events provide no information about future outcomes. The reason is given by the fact that the distribution functions which generated these outcomes are themselves subject to constant change. Expectations on past experience is therefore inappropriate as the distribution function upon which these expectations are based does not project into the future.

In response, it needs to be stated that although the dimensions of the processes governing variables may change (i.e. structural changes), the very existence of certain relationships can be considered as being time independent (hence ergodic) as they reflect the inherent utility maximising behaviour of individuals. Thus, in contrast to Davidson, who sees economics as a summary of non predictable shocks, it is argued as more appropriate to regard it as a stable equilibrium of variables governed by broad relationships, the unique nature of which is subject to modifications depending on the environment within which the relationships are found.

Concerning the stable existence of certain relationships, Davidson (1982:193) maintains that *'all economic data are dated; so that inductive evidence can never do more than establish a relation which appears to hold within the period to which the data refer'*. Although this appears to support his nonergodic argument, it is rather a question of the adequacy of statistical methods. The concept of cointegration, for example, represents a deliberate attempt to identify long-term relationships.

The mere fact that a decision taken today has an impact into the future makes the latter “partly“ ergodic. Sticky wages is a typical example. Wage contracts ensure workers a certain nominal wage in the future, allowing workers to incorporate future wage expectations in their decision making. However, what they do not know, is the real wage, as it depends on the future inflation rate. However, the latter is also a function of current decision making (e.g. wage negotiations) and is therefore not entirely arbitrary. Provided that these linkages between current decisions and future outcomes are considered when forming expectations (thus, forming RATEX), current decision makers are faced by a nonergodic world. Thus, Davidson's argument can be reversed in that RATEX is not based on nonergodicity but is rather a necessary requirement for a predictable future.

#### **2.3.5.2.2. *Nonergodicity and Expectations Formation***

On the basis of nonergodicity, Davidson (1982:189) claims that *'If we do not possess, never have possessed, and conceptually never will possess an ensemble of macroeconomic worlds, then the entire concept of the definition of relevant*



*distribution functions is questionable. It can be logically argued that the distribution function cannot be defined if all the macroinformation which can exists is only a finite part (the past and the present) of a single realisation'. Consequently, no expectations can be formed. Similarly, Rutherford (1984: 383) claims that 'Rational expectation theorists ... assume stable economic relationships, but it can never be known from past history that such relationships will hold up'. Shiller (1978:39) questions the very existence of a RATEX equilibrium in that several time periods have to elapse before adequate data is accumulated to form RATEX, by which point, the structure will have altered. However, as Feltz and Hoogduin (1988) emphasis, these conclusions rest on a probability theory that may not be appropriate in economics.*

Feltz and Hoogduin (1988:106-108) distinguish two forms of probability theories namely frequencies and logical theories. While in the former, probability is defined as a relative frequency of events, in the latter, it is the strength of the relationship between a proposition and its evidence that defines a probability<sup>10</sup>. They conclude that *'in economic theory, the logic theory of probability should be preferred to the frequency theory, because the former is directly connected with the circumstances in which people make economic decisions. People form expectations on the basis of their knowledge , and their logical theory associates (probabilities of) expectations with available knowledge '*. This appears to be in

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<sup>10</sup>. Swamy et al. (1982:127) make the distinction between objective and subjective probability where the former is associated with the frequency approach and the latter with the Bayesian approach. They maintain that any probability approach not based on frequency is necessarily subjective.



line with Keynes who, according to Rutherford (1984: 380) maintains that the probability that can be assigned to a prediction ‘*depends not so much on the number of past experiences upon which we rely, as on the degree in which the circumstances of these experiences resemble the known circumstances in which the prediction is to take effect*’. Thus, Keynes attempts to move probability theory away from the conventional frequency interpretation to a *logical theory of probability in which probability represents the rational degree of belief in a proposition given the evidence*’ (Gerrard 1994:333). Consequently, reduced weight can be given to Davidson’s argument in the light of these conclusions.

#### 2.3.5.2.3. *Rationality Versus RATEX*

Davidson (1982:186) maintains further that *‘if decision makers realise that the future time series data are being generated by important nonergodic situations ... then they will reject the rational expectations taken with respect to the objective distribution functions existing at time  $t_0$ ’ [presence]. In a later article Davidson (1987:149) returns to and extends this conclusion by quoting Hicks: ‘In a nonergodic environment, people do not know what is going to happen and know that they do not know what is going to happen’. Feltz and Hoogduin (1988:115,116) raise a similar point when arguing that *‘people act rationally when they account for possible future events, which cannot be derived from presently knowable objective circumstances and in doing so render expectations exogenous*<sup>11</sup> .... *People behave rationally by not forming all expectations**

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<sup>11</sup>. Exogenous expectations refer to expectations that are either the result of imaginative powers or conventions, norms, institutions and rules of thumb (Feltz and Hoogduin 1988:116-118)



*according to the rational expectations hypothesis, since they know that new knowledge ... may become available when time elapses*'. Thus, rational individuals, being aware of their limitations and a nonergodic future, reject RATEX as these are insensible in such an environment.

One response to the above arguments is that it is always more rational to form expectations through the identification of causal links (weak RATEX) than to rely on an arbitrary formula such as adaptive expectations. On a more fundamental level, it needs to be questioned as to why the awareness of certain limitations regarding future events should prevent individuals from utilising as much information as possible. Indeed, the realisation of possible unknown future events spurs economic agents to accumulate information so as to reduce uncertainty surrounding such potential events. Referring to the above argument of information acquisition, it is incorrect to state that individuals will abstain from acquiring extra information if they are aware of their limitations as they do not know the benefits of such additional information. Thus, the above argument of rational ignorance is appropriate only for the special case where the potential losses associated with false expectations are perceived as trivial by the decision maker. However, such expectations do not require modelling nor do they cause structural instability, as they do not appear to affect economic agents' utility function.

Davidson (1982:149-152) continues by maintaining that the realisation of an unpredictable future leads rational individuals to make sensible expectations relying on social institutions such as money. Hence, Keynes liquidity preference theory is in line with rational individuals but not RATEX as in the latter case, no



precautionary measure needs to prevail: *'Their [liquid assets] utility value lies in preserving flexibility for future actions which is not necessary for inhabitants of an ergodic neoclassical world where rational expectations would make such long run liquidity demands superfluous'* (Davidson 1987:150).

This is a rather puzzling conclusion in that the entire liquidity preference theory centres around expectations. On what grounds other than expectations do individuals balance their portfolio with respect to money and other financial (or real) assets? Davidson is correct in that money is held as a result of uncertainty. However, in the absence of expectations, an individual would hold his entire portfolio in money balances. Unless he holds some expectations regarding future outcomes, there is no basis for determining the amount of passive balances the individual wants to hold. It is more appropriate to regard the need for active money balances as a precautionary measure in the light of errors in expectations, rather than general uncertainty. The precautionary motive of money demand could therefore be seen as being determined by the variance of the forecasting errors.

#### **2.3.5.2.4. *Some Final Remarks and Comments***

Davidson (1982:189) quotes Shackle who maintains that *'the notion of a stochastic process is an unwilling, and elementary insufficient concession to our uneasy consciousness of not knowing what will follow any action of ours'*. This statement is questionable from the perspective of RATEX and in that regard econometrics, as the emphasis is not so much on quantifying future values as it is on the identification of relationships among variables. Furthermore, given that the



error term is (or should be) white noise, no additional insight would be revealed if the error term is replaced by numerous additional variables. Thus, the error term is a deliberate attempt to reduce a model to essential relationships and not a 'concession of uncertainty'.

Davidson (1982:196), referring to Ferguson (1969:269), supports the view that *'Just as ... neoclassic production and distribution theory was not based on scientific foundations but was a "statement of faith" ... Rational Expectation Hypothesis proponents [have to] confess that the applicability of modern neoclassic theory of rational expectations to macroeconomic theory is merely a statement of faith'*. Two comments are worth mentioning. The first refers to the implicit association of RATEX with the Neo Classical theory. As outlined above, RATEX (in particular the weak version) represents a concept on its own and its relevance must be evaluated in isolation to the other New Classical assumptions. The second one refers to the declaration that RATEX relies on a statement of faith. It appears as if this conclusion is more appropriate to adaptive expectations, which, as continuously pointed out, have no theoretical foundation. RATEX do not rely on a statement of faith but rather on one of the basic assumptions of economic theory, namely the assumption of rationality.

## **2.4. THEORETICAL ASPECTS OF POLICY MODELLING WITH RATEX**

The birth of econometrics as a recognised branch of economics is usually associated with the founding of the Econometric Society in the early 1930's by Charles Ross, Irving Fischer and Ragnar Frisch (Basson 1990:84). This development was followed by the Cowles Commission, the latter representing an attempt to formalise econometric practices. The framework of econometric techniques suggested by this Commission has become generally accepted as the benchmark of econometric methodology (Charemza 1991:47).

One of the aims of this chapter is to show that incorporating RATEX into conventional model building provides a solution to the Lucas critique and reinstates these models as appropriate tools for policy evaluation. Consequently, the Cowles Commission's approach as interpreted in this study, is very much relevant and, provided for certain modifications to adequately incorporate RATEX and the problem of non-stationary data, it represents the approach followed in this study. Throughout the following discussion, numerous references will be made to Chapter III in which the estimation and solution method chosen for this study is discussed in detail. The purpose of this Section is to provide only a less technical overview of the general approach followed.

A strict application of the Cowles Commission's approach has not only been criticised in particular by Sims (1980) but is also rarely found in practice. Hylleberg & Paldam (1991:10) maintain that '*strict adherence to the prescriptions*



*of this strategy would lead to rejection of all theories and the practice has thus developed into a trial and error process*'. Applied econometrics has focused on utilising theory as a guideline in specification but it is the combined evaluation of economic, statistic and econometric criteria that will ultimately determine a specification. A final specification could therefore differ to economic theory. However, economic criteria such as the right sign and magnitude of a coefficient should never be compromised.

#### **2.4.1. THE COWLES COMMISSION'S APPROACH TO MODEL BUILDING**

The approach suggested by the Cowles Commission is reflected in almost every modern day standard econometric textbook<sup>12</sup> and is generally referred to as the traditional econometric methodology. It represents a four step approach to econometric research. The first step involves the specification of the model or equations based on the one or other economic theory, followed by the second step of estimating the model according to an appropriate econometric method. The third step comprises the evaluation of the estimates according to economic (sign and magnitude of coefficients), statistical (e.g. t-values) and econometric (e.g. DW or  $R^2$ ) criteria as well as an ex post fitting of endogenous variables in a simulation. The last step pays attention to the forecasting validity of the model (simulation outside the sample range). Should the econometric requirements not be satisfactory, it is customary to re-specify the model (Koutsoyiannis 1977:27-28). Re-specification and estimation will continue until the results pass all the pre-set

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<sup>12</sup>. See, for example, Maddala (1992:4-8) or Koutsouyiannis (1977).



requirements. Although this is not the original methodology of the Cowles Commission, as mentioned in the introduction, this methodology has been the applied outcome of the Commission's recommendations. It follows that the traditional econometric approach is one of recursive optimisation where all three steps are repeated until an optimal model in terms of economic, statistical and econometric criteria is derived.

The Cowles Commission's approach is based on the following principles:

- ◆ Zero restrictions and the role of economics: According to the Cowles commission, economic theory forms the basis of the specification and identification of equations. It provides a priori knowledge regarding the appropriate variables to be included in a particular equation and identifies which of them are exogenous or endogenous. By imposing a priori restrictions, economic theory is supposed to allow the successful application of the rank and order rule for identification. However, as Liu (1960) originally claimed, economic theory cannot be relied upon for identification and zero restrictions will have to be imposed on parameters for the sake of identification (Charemza 1991:48). These restrictions on the other hand, need not necessarily be reconcilable with economic theory (Darnell and Evans 1990:118).

The problem of structural identification has been a popular critique of conventional model building. The argument maintains that for the model to be identified, restrictions (such as zero restrictions) are imposed without necessarily relying on economic theory. The primary proponent of this view



has been Sims (1980), who introduced an alternative approach known as Vector Auto Regressions (VAR models)<sup>13</sup>. This approach requires no specification and prior knowledge of economic theory but rests solely on the belief that every variable is affected by all other variables. Thus, no specification of endogenous and exogenous variables is necessary. However, this approach allows virtually no structural evaluation that could provide insight into empirical validity of economic theory. Furthermore, for policy evaluation, the seriousness of the structural identification problem is of less importance as it is the reduced form of the models that is used. Indeed, this view is supported even by Sims (1980:11).

- ◆ A distinction between endogenous and exogenous variables. According to the Cowles commission, this classification and the resulting causal structure of a model are both given a priori and are untestable (Maddala 1992:389). The distinction delineates the dimensions of the model in terms of the number of structural equations. This distinction is also important for RATEX, as it will identify what expectations require a behavioural specification (this will be discussed in detail in Chapter III). The basis for the distinction depends on the purpose and size of the model.
- ◆ Structural invariance of the parameters: The Cowles commission approach rests on the assumption that both, the reduced form parameters as well as the

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<sup>13</sup>. For a discussion on VAR models, see for example Charemza and Deadman (1992). One application of VAR is given by Granger Causality tests.

structural parameters are constant or a function of time and are not in any way influenced by variables used in the model (Charemza 1991:47). As previously discussed, it is this assumption that the Lucas critique focuses on and that the inclusion of rational expectations can address.

- ◆ Evaluation of the model: The principle criteria for evaluating a model is how well the data it generates fits historically observed data on endogenous variables (Charemza 1991:47). A single equation, on the other hand, is evaluated according to economic, statistical and econometric criteria. The primary critique to this approach has been the argument of data mining, which refers to the selection of a model based on a set of previously estimated alternative specifications (Charemza 1991:48). The model is therefore not independent to previous attempts which increases the probability of accepting significance even though the parameter should be zero. This assumption has also been criticised by Lucas by again referring to parameter changes in the light of alternative policies and consequently, RATEX provides again an answer. However, the problem of structural changes and dynamic stability are inherent difficulties encountered by econometricians so that RATEX must be seen as only a partial solution, addressing model instability originating from alterations in expectations only.
- ◆ Stationarity and equilibrium relationships: An equation specified on economic theory is most often reflecting an equilibrium relationship. While such a specification might be appropriate for long run modelling, explaining short-run behaviour on such a basis could result in rather large error terms. In addition,



most time series are non-stationary which leads to the problem of spurious regression. Both of these concerns can be addressed within the traditional way of structural specification by the cointegration technique in conjunction with short run error correction modelling. This is also the approach chosen in the current study and will be explained in Chapter VII.

## **2.4.2. DIFFERENT APPROACHES TO POLICY MODELLING**

There are several approaches to policy analysis with an econometric model. Whitley (1994:200-215) mentions policy simulation and optimal control techniques. The latter specifies a set of target variables to be achieved by varying policy instruments. These target and policy variables are brought together in the specification of an objective function. This function can be seen as a social welfare (or costs) function which lead Intriligator Bodkin and Hsiao (1996:551-555) to classify this technique as the social welfare function approach. Also mentioned by Intriligator et al. (1996:549) is a third technique, namely the instrument-target approach. Each of these techniques will shortly be discussed.

### **2.4.2.1. Instrument-Target Approach**

The instrument-target approach substitutes desirable values for the policy targets (endogenous variables) into the estimated reduced form model and solves the latter for the appropriate values of the policy instruments (Intriligator et al. 1996:549-551). Should, for example, the inflation rate be considered as the policy target and the interest rate as the respective policy instrument, the desirable

inflation rate will be substituted into the model and the latter solved for the required interest rate. This approach has, however, the disadvantage that it could produce levels of policy instruments quite unfeasible for actual implementation. This is particularly the case when the policy target is affected by numerous factors, not just the policy instrument (this is particularly relevant when intermediary targets are involved). The desirable interest rate level would be of little use to a central bank in such an instance. However, of far more interest to the policy authority would be responses of the policy target to changes in the policy instrument in order to identify, for example, policy multipliers and linkages within the economy. This approach is therefore rather restrictive and denies the full exploitation of a model's usefulness.

With regard to RATEX, this approach is well capable of accommodating the different policy considerations. When solving the model, the different assumptions regarding policy anticipation are simply incorporated into the model before solving it. As discussed in Chapter V, the Reserve Bank sets intermediary targets and its actual target is subject to numerous other factors than just the policy target. Consequently, this approach is believed to be inferior to other alternatives and will consequently not be pursued in this study.

#### **2.4.2.2. Social Welfare Function Approach**

The social welfare function approach involves the maximisation of a social welfare function subject to the restrictions reflected by an econometric model. In a linear model where the welfare function (or loss function) is quadratic, this



technique gives a control policy in the form of a linear feedback rule for the policy instruments (Intriligator et al. 1996:551-555, Whitley 1994:209). This approach has a certain appeal for a South African application in that the mission statement of the Reserve Bank (see Chapter V) indirectly specifies a welfare function. However, whether this function would take account of all aspects to be truly classified a social welfare function is questionable. How to determine the parameters of such a function and consequently an optimal linear policy rule has been shown by Chow (1981) also for the case of RATEX.

Chow (1981:225-238) uses a linear decision rule in his illustration of how to use optimal policy control methods in the case of RATEX:

$$x_t = G_t y_{t-1} + g_t$$

where  $y_{t-1}$  represents the policy target and  $x_t$  the policy instrument.

To ensure RATEX, he substitutes this rule into the model to eliminate policy target expectations. The parameters of the decision rule are then obtained through ordinary constrained optimisation (Chow 1981:241-242). He maintains and shows that this prevails even when future expectations of policy instruments are involved by solving such a model through substitution (while making additional assumptions to address the multiple solution problem (1980:228)). He (1980:236) concludes that '*optimal control theory is still*<sup>14</sup> *applicable when current decisions*

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<sup>14</sup>. Chow responds to an article by Kydland and Prescott (1977) in which they advertised the death of optimal control theory in the presence of RATEX on grounds of time inconsistency. The

*of economic agents depend in part upon their expectations of future policy actions .... if the effects of future expectations are properly incorporated ... [as described above].*

There are two objections to the welfare function or optimisation approach and Chow's statement. Given that the optimal policy rule will only be known once the optimisation problem is solved, this rule is not known for the estimation period. Thus, although model specification will substitute the optimal rule to address RATEX, the behaviour of economic agents, and consequently the data used for estimation, does not reflect this rule as it has not been known. Consequently, the parameters reflect different RATEX processes and will therefore change once the optimal policy rule is announced. The Lucas Critique is again prominent. It follows that once expectations concerning policy instruments are rational, this approach fails to derive an optimal policy. The latter would be based on an estimated model, the parameters of which reflect RATEX on the existing policy rule or expectation process. The second criticism is given by the fact that this approach fails to allow a distinction between anticipated and unanticipated policies in that only anticipated policies (as reflected by the substitution of the decision rule) are addressed.

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latter refers to the fact that an optimal policy solved for the period  $t+s$  and introduced in period  $t$  might not be optimal any more in period  $t+s+1$  if RATEX are present. Sheffrin (1996:79-89)



### **2.4.2.3. Simulation Approach**

The third and most appropriate method to use in this study is the simulation approach where a simulation of an econometric model is carried out under several assumptions concerning the policy instruments and RATEX formation. Thus, different values for the policy instruments are substituted into the model and the latter is solved in order to evaluate the impact on the policy targets. This comparison is done by first running a base-run simulation which refers to a simulation where the policy instruments have not been changed. This is then followed by a policy simulation where the policy instruments have been altered. Base-run and policy simulations are then evaluated to measure the impact of the policy change. In a similar fashion, this approach addresses the three aspects of policy reactions addressed under Section 1.3.2.2. Every time a simulation is carried out, the assumptions concerning policy anticipation have to be specified and in this fashion all possibilities can be addressed (see Chapters III and IV for the way in which to incorporate these assumptions into model simulations). Therefore, this approach is capable of giving empirical meaning to the above specified three cases any policy proposal should consider in its evaluation and in that regard addresses the Lucas critique. Thus, in the presence of RATEX with regard to policy instruments, this approach appears to be the only feasible technique. This conclusion is further supported by the shortfalls of the social welfare function as well as the instrument-target approach.

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provides a number of examples in this regard.

#### **2.4.4. MODEL BUILDING AND EVALUATION**

In line with the above discussion, the model of this study will firstly, be specified (including expectations) on the basis of economic theory, relevant institutional features and data characteristics, then estimated (as discussed in Chapter III, first the expectation equations, then the rest of the model) and finally evaluated by means of the above criteria as well as on the basis of in and out of sample simulations. In evaluating a model built for policy evaluation, additional criteria such as impact and total multipliers need to be considered. In terms of RATEX, some of these aspects require different interpretations, an aspect also addressed in the proceeding Chapters.

#### **2.5. CONCLUSION**

Conventional macroeconometric models lost most of their credibility in the early 1970's. This was not so much caused by the changing global environment leading to poor forecasts, as it was the increased dissatisfaction regarding their specification. In particular, it was the way in which expectations were accommodated and the lack of incorporating the supply side of the economy in these models that arouse much theoretical criticism. Macromodels in the Keynesian tradition implicitly assume that expectations are like weather forecasts<sup>15</sup>

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<sup>15</sup>. It is Hoover (1992:88) which makes this useful distinction between weather forecasts (all agents can treat forecasts as independent of their own behaviour) and water-use forecasts (forecasts which alter the behaviour of agents).



in that agents can treat them as independent of their own behaviour<sup>16</sup>. The conventional way of specifying such expectations has been the use of an adaptive expectations model where expectations are based on a formula of past errors and values of variables. However, this approach appeared to represent more of a stopgap than a proper theory of expectation formation. Adaptive expectations are irreconcilable with the rationality assumption underlying all structural equations and lacks theoretical foundation. However, the key critique of adaptive expectations is that they introduce structural instability. At the crest of this attack was Lucas' argument that structural parameters are not invariant to policy alterations in models with adaptive expectations. This implied the denial of any useful policy modelling with these conventional models and consequently questioned their *raison d'être*. This is best summarised by Hoover (1992:88) when he maintains that *'using large-scale [conventional] macroeconomic models to make conditional forecasts makes no sense. First, these models are, at best, incorrectly specified, [because they utilise adaptive expectations].... Second, policy experiments are incorrectly conceptualised in them - issues such as dynamic consistency were not faced. Finally, they simply are not accurate representations of economic structures that would remain invariant to changes in the policy regime'*.

According to Lucas, the reason for this instability is given by the fact that individuals form their expectations not by adhering to an unfounded formula but rather by utilising all available information and in that way base expectations on the actual process governing the variables. Such expectations are reconcilable with

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<sup>16</sup>. Indeed, some models like the IS-LM model rise or fall with this assumption.



the rationality assumption and extend the conventional practise of model specification to the sphere of expectation modelling. They are indeed rational expectations (RATEX). But RATEX provide not only the foundation for the Lucas critique, incorporating them into econometric models represents also the best way to address the problem of structural instability. Through the application of RATEX, policy invariant parameters are ensured and in that way, econometric modelling according to the Cowles Commission's methodology becomes again useful for policy evaluation. However, when RATEX are formed not only on endogenous variables but also on policy instruments, a distinction has to be made between whether a policy was anticipated or not and should it not have been anticipated, the extent to which this influences the expectation equation of the policy instrument in future. Thus, with regard to expectations of policy instruments, the inclusion of RATEX does not provide an answer per se but rather the rationale for proper assumptions regarding policy responses. Allowing for RATEX on policy instruments also limits the choice of an approach to policy evaluation in that only the instrument-target and simulation approaches are appropriate where the latter is the more attractive one to use.

The RATEX hypothesis has several other advantages than simply addressing the Lucas critique. In that regard, Hoover (1992:90) maintains that '*although it has been criticised on conceptual grounds and as empirically adequate, the rational expectations hypothesis sets a noncontroversial standard of modelling expectations in macroeconomics. Alternative approaches are either out of the academic mainstream (...the notion of bounded rationality) or are positively shunned (all adaptive and extrapolative approaches)*'. Similarly, Turnovsky



(1984:58) argues that *'one of the most compelling arguments in favour of the rational expectation hypothesis is the weakness of the alternatives ... Traditional expectation schemes involve systematic forecasting errors ... By contrast, the rational expectation hypothesis generates expectations that are self fulfilling to within a random error'*. Finally, Barro (1984:179) states that *'much of the rational expectations view - that expectations are formed sensibly given the information people have [weak form] ... - has been generally accepted. This viewpoint has permanently and usefully altered the way that most macroeconomists build models and carry out evaluations of shifts in governmental behaviour'*.

Critics, on the other hand, have maintain that RATEX makes unrealistic assumptions regarding information availability and is founded on the unrealistic notion of an ergodic future. However, once these criticisms are evaluated more closely, they lose much of their relevance and persuasive power. The incorporation of RATEX provides not just the only feasible way to overcome the Lucas critique within conventional econometric methodology, it also represents a theory of expectations formation far superior to its alternatives. This statement is supported by the increased use of RATEX in econometric model building.

The model considered in this study will be built within the tradition of the Cowles Commission's methodology of specification, estimation and evaluation. The Lucas critique will be addressed by incorporating weak RATEX of policy instruments and other endogenous variables while non-stationarity is addressed through the application of cointegration methodology. Given that the focus is on policy simulation, the reduced form of the model is of particular relevance and will be

evaluated accordingly. How to estimate this model will be discussed in the next chapter.



## **CHAPTER III : SOLVING AND ESTIMATING A MARCOECONOMIC MODEL WITH RATIONAL EXPECTATIONS**

### **3.1. INTRODUCTION**

The previous chapter has shown that incorporating RATEX into conventional econometric model building represents a feasible way to overcome the Lucas critique. However, accomplishing such a task involves the mastering of a number of hurdles. These refer in particular to the solving of such a RATEX model where queries concerning uniqueness and stability appear. However, as shown below, the extent to which these aspects represent problems depends on the choice of the solution technique.

The solving of a RATEX model refers in the first instance to the substitution of unobservable expectations variables by observable variables so that estimation can be undertaken. Two approaches exist for this task namely the Substitution Method and the Errors in Variable (EV) method. In the former, the mathematical expectations of the model are derived and these are then solved and re-substituted into the model. In explaining how RATEX addresses the Lucas critique in Section 2.3.2., this approach was made use of. The EV method on the other hand, eliminates the expectations variable by substituting the actual variable into the model. Given, however, unfavourable econometric implications, the expectations

variable is generally replaced by an estimate in the form of an instrumental variable.

The solution of a RATEX model, or more appropriately, the observable form of the RATEX model, requires special evaluation, particularly when not only expectations on the current period but also on the future are included. In that case, it needs to be established whether the solution is unique or whether other observable models can be derived from a similar RATEX model. This centres around the question of several solution paths and the presence of a saddle point solution. The second aspect to consider is whether this solution path is stable or not. These two aspects, namely uniqueness and stability, are closely interwoven and require therefore joint evaluation. Ideally, the solution should be stable and unique.

The discussion will start out with a general evaluation of the whole question of uniqueness and stability of a RATEX model with future expectations. In Section 3.3, the Substitution Method is covered with particular emphasis on the necessary requirements for a stable and unique solution. The disadvantages of this technique are also considered. Section 3.4 will introduce the EV method. Particular emphasis will fall on the estimation of the model while the question of uniqueness and stability will also be addressed. This section also serves as the theoretical foundation upon which the practical aspect of this study will be built.



### **3.2. GENERAL DISCUSSION OF UNIQUENESS AND STABILITY IN LINEAR RATEX MODELS**

An economic model is said to be globally stable if any shock to the economy the model represents will always be followed by a convergence of the model to a new steady state. The relationships reflected by the model are then of such a nature that they will counteract any disturbances and ensure the perpetuation of the equilibrium relationships defined by the model. No internal nor external forces exists that would cause the system to divert from its long term stable path persistently. There is therefore a natural tendency for the variables in such an economic system to move towards a state of zero change. The factors determining this tendency and hence the existence of a stable path are the signs and magnitudes of the coefficients defining the dimensions of the relationships.

The property of stability reflects the very foundation of the economic concept of general equilibrium (or general harmony within the economy) and is necessary for any economic modelling to occur if the latter is to be used for out of sample forecasts or meaningful policy simulations. Only under the assumption of equilibrium relationships can a set of variables be simultaneously projected. Similarly, a policy simulation aims at either ensuring the return to equilibrium from a state of disequilibrium or from a different and less desirable equilibrium level. A simple example of this concept is given by the functioning of a stable market. Any price other than the market clearing one will initiate forces that will be directed towards market clearing. Even if prices are sticky and actual market clearing never occurs due to dynamic changes, a tendency exists towards market



clearing which will ensure that the supply-demand relationship remains stable over time within a random error. No external shocks will therefore persist indefinitely.

Similarly, an economic system is said to be globally unstable if any change in a variable is not directed towards the state of zero change but actually induces further change. Unless the economy is in a state of zero change, it will never be able to reach a stable path. Consequently, no stable relationships can be identified and econometric modelling is not meaningful. An example of such a state was given in the previous Chapter when discussing the Cobweb model. If demand is fairly inelastic and supply elastic, price adjustments will not lead to a market clearing situation but will diverge supply and demand even further. A state of zero price change is therefore never achieved. In reality, such a state cannot persist indefinitely. Eventually forces will develop that will alter this tendency. Therefore, it is essential to properly specify model relationships to ensure dynamic stability.

Besides the two extreme situations of global stability and instability, a third case can arise in that the economy converges to a stable equilibrium path only if the economy finds itself on a specific convergence path. Unless this prevails, the economy will be unstable. There is therefore only one possible way or path the economy can go to its stable state and this path is then referred to as a saddlepoint (Begg 1982: 35). While in general, such a path will be considered as undesirable in that convergence cannot be ensured, it becomes of absolute importance in RATEX models as forward expectations can be based on a single path.



RATEX on future variables require that the individual anticipates the dynamics of the economic system as these expectations are forward looking. The individual has therefore to anticipate the path the economy proceeds on to be able to form his expectations. Should global stability prevail, an indefinite number of convergence paths exists and the individual does not know which path the economy follows as all of them will lead to the same outcome. This is the problem of non-uniqueness. Different individuals will utilise different convergence paths when forming RATEX and will consequently have different expectations regarding the dynamics of the system and changes of variables. A model incorporating future RATEX variables can therefore be associated with numerous observable models. Stated differently, the solution of a RATEX model is not unique. It is only in the presence of a saddle point, i.e. a single convergence path, that a unique solution can be guaranteed. Given that individuals are forward looking, they will identify this path and therefore ensure that stability will be achieved <sup>1</sup>. They have no tendency to alter their RATEX as they are confirmed and will therefore enforce this convergence path. To build an econometric model with RATEX, it is therefore essential to ensure stability and uniqueness, which implies a unique convergence path or the presence of a saddlepoint. As Burmeister (1980: 800-801) states it: ‘*The most crucial issues in rational expectations modelling ... concerns the dynamic properties of rational expectations paths and the manner in which the stability properties of these expectations serves to make determinate the stochastic properties of the actual variables*’.

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<sup>1</sup>. This differs from Adaptive Expectations where such a conclusion cannot be derived as expectations are backward looking (Begg 1982: 37).



The responses to the multiple solution problem of RATES models have been a divergent spectrum of opinions. Shiller (1978:33) for example, maintains that '*the existence of so many solutions to the rational expectations model implies a fundamental indeterminacy for these models*'. McCallum (1983: 140,144), on the other hand claims that '*non-uniqueness is simply an inescapable aspect of dynamic models involving expectations, one which is not basically attributable to the rationality assumption. Instead, the appropriate conclusion seems to be that any dynamic system with expectations variables will have multiple solutions if extraneous terms are permitted to influence expectations*'. The extraneous term refers to a component that affects agent's expectations but is not suggested by the model. Therefore, such a component will lead to different expectations on the convergence path of the economy and hence different solutions. As McCallum (1983: 143-144) rightfully claims and illustrates, this is valid for RATES as well as other expectations processes such as adaptive expectations<sup>2</sup>. Salemi (1986: 62-63) further maintains that non-uniqueness is of less practical significance than previously thought and that it does not preclude estimation of the model's parameters.

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<sup>2</sup>. At first, the concept of an extraneous component appears to contradict the concept of RATES in that this component does not appear in the model. McCallum (1983: 145) maintains however, that such an incorporation allows the formalisation of concepts such as speculative bubbles within the RATES methodology. More broadly then, any temporary deviation from a convergence path could be associated with extraneous factors. In the presence of global stability, they will therefore result in multiple solutions while in the case of a single path temporary deviations, such as speculative bubbles, will occur. A saddlepoint is therefore only possible if no extraneous terms exists or they are all of the same dimension in the presence of global stability.



### 3.3. THE SUBSTITUTION METHOD

As indicated, the Substitution Method requires solving the model by taking expectations conditional on the model and then solving for these expectations so that they can be substituted back into the model. In the case of backward looking expectations, this process is easily accomplished. However, in the case of future expectations, the equation representing the expectations variable will continue to have a future expectations variable. Continuous forward substitution can only eliminate this unobservable variable if certain requirements are met. These will now be discussed.

#### 3.3.1. UNIQUENESS AND STABILITY REQUIREMENTS

##### 3.3.1.1. Theoretical Discussion

Given the system of multiple equations:

$$BY_t + \sum_{i=0}^{\lambda} AY_{i,t+1}^e + \Gamma x_t = u_t \quad (1)$$

where  $\lambda$  refers to the expectations horizon i.e. the number of future time periods for expectations formation and B, A and  $\Gamma$  are matrixes of dimension  $n \times n$ ,  $n \times p$  and  $n \times m$  respectively, given  $n$  endogenous variables. P refers to the number of endogenous variables for which expectations are formed. These are also the first  $p$  elements of  $Y_t$ .

The reduced form is given by

$$Y_t = -\sum_{i=0}^{\lambda} B^{-1} A Y_{t+1}^e - B^{-1} \Gamma x_t + B^{-1} u_t$$

or

$$Y_t = \sum_{i=0}^{\lambda} \Pi_{1i} Y_{t+1}^e + \Pi_2 x_t + B^{-1} u_t$$

which can be written as

$$Y_t = \Pi_{10} Y_t^e + \sum_{i=1}^{\lambda} \Pi_{1i} Y_{t+i}^e + \Pi_2 x_t + B^{-1} u_t$$

Taking conditional expectations of the first  $p$  elements (represented by the index 1) under the assumption that exogenous variables are known and the error term is uncorrelated results in :

$$(I - \Pi_{10}) Y_{1t}^e = \sum_{i=1}^{\lambda} \Pi_{1i} Y_{1t+i}^e + \Pi_{21} x_t \quad (2)$$

Thus, expectations for period  $t$  depend on all future expectations as well as the exogenous variables. Equation (2) represents  $p$  simultaneous linear difference



equations of order  $\lambda$ . The higher order  $\lambda$  can be transformed to  $\lambda$  single order equations so that equation (2) can be written as  $\lambda p$  simultaneous first order difference equations (Chiang 1984: 606-608). In order to derive a solution, the time path of each of the  $p$  endogenous variables needs to be determined and evaluated<sup>3</sup>. According to Chiang (1984: 554), the general solution will consist of two components, namely a particular or integral solution and a complementary function.

The particular solution represents the equilibrium level while the complementary function signifies the deviation of the time path from that equilibrium (Chiang 1984: 554-555)<sup>4</sup>. Consequently, the sum of those two components gives the actual time path of the variable in question. The solution for the partial solution or integral depends on the assumption underlying the time series. If the time series is assumed to be stationary, the partial integral will be a constant. Alternatively, should the series have a deterministic trend, the solution will be a linear function of time (see Chiang (1984: 555-556) for an example).

The complementary function is derived from the reduced form (setting equation (2) = 0) by substituting an initial (or trial) solution and solving then for the coefficients determining the complementary solution, the latter being a function of time. The coefficients of the complementary equation will be a function of the coefficients of the difference equation so that requirements for the latter (e.g. the

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<sup>3</sup>. For a simplified discussion and example of forward solutions within the context of rational expectations, see Enders (1995: 48-53).

requirements for stationarity) can be specified through assumptions concerning the complementary equation.

To avoid that the trial solution delivers trivial results (the coefficient of the complementary function equals zero), initial requirements have to be set. In the case of simultaneous difference equations, this requirement is given by the fact that the coefficient matrix of the reduced equations after substitution must be singular, i.e. it must not have an inverse, implying that its determinant must be zero:

Given the system of simultaneous  $p\lambda$  first difference equations

$$Y_{t+1} - KY_t = 0 \quad (3)$$

where  $Y$  is a vector of  $p\lambda$  variables and  $K$  a  $(p\lambda)(p\lambda)$  matrix.

Given further that the trial solution for the complementary equation is given by

$$Y_{t+1} = nb^{t+1} \quad (4)$$

the aim is to determine the coefficients of (4) i.e.  $b$  and  $n$ .

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<sup>4</sup>. A simple illustration of the following discussion is given by Chiang (1984: 554-557). For an alternative discussion on difference equations and their solutions see Enders (1995: 1-20, 25-35).



Substituting (4) into (3) results in

$$[nb^{t+1}] - [Knb^t] = 0$$

or

$$[nb^{t+1} - Knb^t] = 0$$

which can be written as

$$[b^{t+1} - Kb^t]_n = 0$$

or

$$[H]_n = 0$$

(5)

where  $H$  is a  $(p\lambda)(p\lambda)$  matrix

One solution would be that  $n=0$ . This is the trivial solution mentioned above. It implies that all endogenous variables are zero. To avoid this result matrix  $H$  must be singular, i.e. it must not have an inverse which implies that its determinant must equal zero:

$$\text{Det}(H)=0$$

(6)

The determinant of  $H$  is a function of the elements of matrix  $H$ . Thus, the coefficients ( $b_j$  and  $k_{ji}$ , where  $j$  and  $i = 1, 2, \dots, p\lambda$ ) have to be determined in such a way that equation (6) holds. The above equation therefore provides a solution for the coefficients and can therefore be defined as a characteristic equation. However, given that the solutions of equation (6) are usually referred to as eigenvalues, the solution for the complementary equation is given by matrix  $H$ 's eigenvalues.

Equation (6) needs to be solved for the  $p\lambda$  values of  $b_j$ . Thus, the  $p\lambda$  eigenvalues of  $H$  represent the solution values for  $b_j$ . However, from the complementary equation (4) it follows that the particular time series will only be stationary (or non explosive) if the relevant  $b_j$  coefficients are smaller than 1. Consequently, the stationarity of equation (2) is only given if all eigenvalues are smaller than one. Only then will the time series converge to a constant ( $\lim[b^t] \rightarrow 0$  as  $t \rightarrow \infty$  only if  $b < 1$ ) so that in the limit, forward substitution will eliminate the expectations variables in equation (1), allowing future expectations to be modelled entirely by exogenous future values<sup>5</sup>.

The previous discussion has shown that in the Substitution Method, stable paths of endogenous variables are required in order to solve for their future expectations. This stability requirement needs to be tested by looking at the complementary equation of the relevant first difference equations. However, the task is not completed. Having obtained values for  $b$  under the constraint that  $n$  must not be



zero leaves numerous other solutions open for  $n$ . The complementary equations are therefore not unique. A particular value for  $n$  needs to be determined. This is achieved by utilising so called initial conditions or boundary values. These values are substituted into the complementary equations and the latter solved for their respective  $n$  values.

### 3.3.1.2. General Discussion

An interpretation of the above discussion can be given by referring to the general discussion in Section 3.2 <sup>6</sup>. The coefficient  $b$  reflects the magnitude of change the variable will experience within one period. The system is considered as stable if any shock to the time path of a variable leads only to temporary deviation of that variable from its long term path (partial solution). Thus, the complementary equations of such variables must all have negative  $b$  coefficients strictly between zero and one. Only if this is the case, will global stability prevail as each variable will have a tendency to return to its long term value (a state of no change) irrespective of the value of  $n$ . Thus, all possible path of a variable will reflect stability.

However, having obtained a value for  $b$  says nothing about the actual path that variable follows. As indicated, to determine the latter, a unique value needs to be

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<sup>5</sup>. Should  $b < 1$ , the complementary equation will tend to zero, making the equilibrium dynamically stable in that the variable will converge to its partial solution.

<sup>6</sup>. For a general interpretation of the coefficients of the complementary equation see Chiang (1984: 557-561).

determined for the arbitrary constant  $n$  which requires the knowledge of an initial value of the variable. It is because of this arbitrary constant that the Substitution Method has to rely on so called terminal or boundary conditions and in the process determines a unique path.

The concept of a saddlepath, i.e. the situation where only one convergence path exists, can also be explained by the newly gained knowledge. A saddlepath implies that unless the economy is on that path or immediately jumps on to it after a shock, no convergence is possible. Each variable is individually explosive, but jointly they form a system of simultaneous difference equations that can be stable. The requirements in terms of eigenvalues clearly differ in that case. If all eigenvalues are smaller than one, global stability prevails. Each variable has an inherent tendency to converge to a particular variable or trend, independent of the other variables (see the graphical representation of Begg (1982: 35) for confirmation). Numerous convergence path (numerous  $n$  values) are possible as the choice of  $n$  has no effect on convergence. In the saddlepath case, it is the unique simultaneous relationships, as reflected by the structural coefficients, that provide dynamic stability. However, to identify the requirements in terms of eigenvalues for a saddlepath, an alternative matrix needs to be evaluated. This is discussed below.



### 3.3.1.3. Conditions for a Saddlepath

A different approach to uniqueness and stability can be derived at when evaluating the eigenvalues of matrix  $A_i$  in equation (1). For illustration, assume the simplified model of above where  $\lambda = 1$ :

$$Y_t + A^* Y_{t+1}^e + \Gamma^* x_t = u_t^*$$

or

$$Y_t = -A^* Y_{t+1}^e - \Gamma^* x_t + u_t^* \quad (7)$$

If the diagonal values of  $A^*$  are smaller than one, i.e. the eigenvalues of  $A^*$  are bigger than one, the solution will be unstable. This is based on the fact that equation (7) can be written as:

$$Y_{t+1}^e = A^{*-1} Y_t + \Gamma^{**} x_t + u_t^{**}$$

Taking expectations, this can be written as

$$Y_{t+1}^e = A^{*-1} Y_t^e + \Gamma^{**} x_t \quad (8)$$

For this system to be globally stable, the diagonal values of  $A^{*-1}$  have to be less than 1 so that the time series processes of  $Y_t^e$  are all stationary. In this case,  $Y_{t+1}^e$

can be obtained through backward substitution as can easily be tested from equation (8). However, uniqueness is not guaranteed as all time series processes will converge independently of the nature of disturbance (Blake 1991:43). The non-uniqueness problem arises as the future path of  $Y_{t+1}^e$  cannot be determined as in the limit, forward substitution will not eliminate the expectations term. In such a case, use can be made of terminal values or conditions, values that will replace the expectations value. Preferably, this should occur a substantial distance into the future to reduce the influence the terminal conditions will have on estimation and simulation.

In the case where all the diagonal values of  $A^*$  are  $< 1$  (or eigenvalues  $> 1$ ), the processes governing  $Y$  is non-stationary, leading to instability. However, in the limit, forward substitution will eliminate the expectations term on the right hand side of equation (7) so that a unique expectations value or path can be determined. Therefore, should all eigenvalues of  $A^* > 1$  a saddlepath exists (for proof, see Blanchard and Kahn (1980))<sup>7</sup>. Should some of the eigenvalues of  $A^*$  be smaller than one, the system will be unstable and non-unique.

### **3.3.2. HOW DOES THE SUBSTITUTION METHOD ADDRESS STABILITY AND UNIQUENESS ?**

As indicated above, to determine the path of a variable requires the determination of an arbitrary constant. To give this constant a meaningful value, the Substitution Method utilises particular selection criteria such as economic optimality,



stationarity, minimum variance or minimal use of state variables (Pesaran 1982: 96-105). Each of these criteria is aimed at the identification of a unique complementary equation and more specifically, a unique value for  $n^8$ . - However, two questions arise (Blanchard 1983: 30):

Is the imposition of such a condition justified? If nonstationarity or explosiveness is inconsistent with the model, i.e. no dynamic equilibrium prevails, the imposition of terminal values can be useful to derive a suitable model. On the other hand, should parameter estimates indicate instability, imposing additional conditions could be inappropriate if the origin lies with model misspecification.

What terminal conditions should be used? Unless the model or its assumptions provides an adequate answer (e.g. optimisation), the choice is arbitrary which could cause that the solution to the model to be a function of the terminal conditions.

Given that the solution technique chosen in this study is not the Substitution Method, on grounds discussed below, there is no need to evaluate and explain each of the selection criteria. All that needs to be mentioned is that different unique paths can be derived depending on which of the selection criteria is chosen. This is generally seen as an unfortunate aspect of the Substitution Method.

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<sup>7</sup>. This conclusion is obtained under the assumption that none of the expectations explodes too fast in that exponential growth is ruled out (Blanchard and Kahn 1980:1305, 1307).

### 3.3.3. DIFFICULTIES IN THE APPLICATION OF THE SUBSTITUTION METHOD

In line with the above discussion, all forward looking expectations variables can be expressed as a function of future exogenous variables. However, the coefficients of the latter are non-linear functions of the original structural parameters and the parameters governing the time series process of the exogenous variables (Begg 1982: 96-97). According to Wickens (1982: 55, 59), to obtain fully efficient estimators, a non-linear estimation procedure is required in this case. This, in term, could involve substantial computational difficulties.

A drawback already addressed in the previous section is the dilemma of multiple solutions. This problem is actually the outcome of the Substitution Method rather than RATEX per se. To solve the model, the future expectations variables are substituted for by a process, the uniqueness and stability of which depend on numerous criteria and assumptions. A stable and unique solution can therefore not be assumed outright but needs to be determined and derived at. As indicated below, no such complications occur in the application of the EV method, making the latter a much favourable solution technique, a statement supported by Blake (1991: 64) : *'Because the restrictions involved in the Substitution Method are , in general, considerably more complicated than those of the EV method and because of the arbitrary way in which the Substitution Method deals with multiple solutions..., the preferred solution technique is the EV method '*.

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<sup>8</sup>. See for example, McCallum (1983) for an illustration of how the minimum state variable



### 3.4. THE ERRORS IN VARIABLE METHOD

In the previous Chapter, RATEX were defined as expectations based on the actual process determining a variable. This lead to the conclusion that RATEX are equivalent to the actual value of the variable plus a stochastic but random error term:

$$x_t = x_t^e + e_t \quad (9)$$

It follows that an alternative way to solve a forward looking model is by substituting the actual values for the expectations. This, however, introduces an error term  $e_t$  as the actual value is only an approximation of the expectations. Given resulting negative econometric consequences, the expectations are replaced by a proxy of the actual variable. Thus, the expectations variable is approximated by its actual value and the latter by an estimated proxy.

The proceeding sections will focus more closely on the distinction between actual, expectations and approximation variables in terms of estimator properties and in terms of the implications for policy evaluation. Section 3.4.1.2. will then outline the way in which the EV method addresses the issues of uniqueness and stability.

### 3.4.1. ESTIMATION PROCEDURE

Substituting the actual for the expected value, followed by an ordinary application of a linear estimation technique such as OLS results in the disappointing situation that the OLS estimators would be inconsistent unless cointegration prevails among the variables (Blake 1991: 37). This inconsistency is the result of a correlation between the error term and the dependent variables (Cuthbertson, Hall and Taylor 1992: 164):

Given the single equation

$$y_t = \beta_0 + \beta_1 x_t^e + v_t$$

Substituting the actual value based on equation (9):

$$y_t = \beta_0 + \beta_1 x_t + w_t$$

where

$$w_t = v_t - e_t$$

From equation (9) it follows that  $x_t$  and  $e_t$  are correlated. This implies that  $w_t$  is correlated with  $x_t$ . The error term is therefore not linearly independent which is a



violation of the assumptions underlying the Gauss-Markoff Postulate, leading to inconsistent and downward bias ( $x_t$  is negatively correlated with  $w_t$ ) estimators<sup>9</sup>.

The solution to the above is to find a variable independent from the error term (an instrumental variable). This independent variable must show high correlation with the independent variable on the one hand and no correlation with the error term on the other. In general, it can be quite difficult to find a good instrumental variable as emphasised by Kennedy (1985: 115-116). However, the RATEX theory, as specifically outlined below, virtually specifies the auxiliary equations that will generate suitable proxies for the independent variables. The EV method can be summarised as follows:

1. Estimate instrumental variables to comply with econometric criteria and RATEX assumptions
2. Estimate the equation after the instrumental variable has replaced the expectations variable.

Utilising the IV method has not only econometric advantages. Utilising the actual variable implies that individuals will always know the actual model of the economy. Thus, this approach would always enforce the strong form of RATEX. As discussed above, this version is lacking realism particularly in the light of

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<sup>9</sup>. Consistency requires that both, biasness and estimator variance tends to zero if the sample size increases. If error term and regressor are correlated, OLS will be inconsistent as illustrated by Steward and Wallis (1981: 117).

changing policy regimes and in that regard fails to address the Lucas critique. Substituting the actual value implies that the individual always anticipates policy changes. It is therefore not possible to evaluate unanticipated policy changes within the framework of weak RATEX. The IV method, on the other hand, allows the identification and separation of the expectations processes from the actual model.

Should the policy instrument be changed in an unanticipated way, the question arises as to what the instrumental equation represents. Does it represent an approximation of the actual value or does it represent the expectations process? The instrumental equation will be a bad estimate of the policy value but so will be the expectations. The instrumental equation could therefore be seen as a proxy for the expectations process as the actual value is clearly inappropriate. But when the IV variable represents a proxy for expectations, an error term is again introduced and inconsistent estimates would be derived. The answer to this difficulty lies in the distinction between estimating the parameters and using the estimated model for policy evaluation.

When the model is estimated, it is assumed that all policy is anticipated in that an equation is specified that will bring the best fit over the entire period. Estimated variables, actual variables and expected variables should therefore follow each other closely. The justification for this assumption lies with the definition of RATEX in that individuals will adjust their expectations to ensure a random error term. In this case therefore, the IV variable is a proxy for the actual value and consistent estimators are obtained.



In the case of unanticipated policy changes, the time series representing a proxy for the actual value of the policy instrument is inappropriate in that a structural break has occurred. Similarly, the actual value has no relation to the expectation variable in that the former was unanticipated. Therefore, in this case, it is more appropriate to regard the instrumental equation's estimate as an approximation of the expectations. While such a definition would result in inconsistent estimators during estimation, it will have no such effect within the context of policy simulation. In conclusion it can be said that for the purpose of estimation, the instrumental variable will be considered as an approximation of the actual value. This will also be the case for anticipated policy changes. For the purpose of unanticipated policy simulation, on the other hand, the instrumental equation becomes an estimate of the expectations process.

Besides RATEX assumptions, numerous other factors determine the equation specification of the instrumental equation. This and further aspects of estimation are discussed in greater detail in the proceeding section.

### 3.4.1.1. Estimation with IV

#### 3.4.1.1.1. *Basic Characteristics and Aspects*

Consider the following model for estimation purposes

$$y_t = \beta_0 + \beta_1 Z_t^e + \beta_2 P_t + v_t \quad (10)$$

Substituting the actual value:

$$y_t = \beta_0 + \beta_1 Z_t + \beta_2 P_t + w_t$$

The auxiliary equation for  $Z$  can be specified as follows:

$$Z_t^* = \alpha_0 P_t + \alpha_1 X_t + u_t \quad (11)$$

where  $X_t$  includes variables closely correlated with  $Z_t$ .

Substituting this forecast into equation (10) results in

$$y_t = \beta_0 + \beta_1 Z_t^* + \beta_2 P_t + v_t^* \quad (12)$$



Equation (12) is the solution of equation (10) in that all variables are quantifiable. The reason for the inclusion of  $P$  in equation (11) is that all independent variables have to be included in the auxiliary regression to ensure consistent estimators. However, increased multicollinearity is introduced as the forecast is partly a linear function of the other regressors. If no other but all the dependent variables are included, the estimate represents a linear function of the regressors which would make the regressor matrix singular.

The variance of the IV estimator is much larger than that of conventional OLS estimators (Kennedy 1985:121-122). This is caused by reduced utilisation of information, resulting necessarily in a lack of efficiency among the IV variables' estimators. It is therefore important to get a high correlation between the IV and the original regressor. If the actual value is an endogenous variable, its reduced form equation can be used as a foundation for specifying the instrumental equation. Thus, the latter would primarily contain regressors of the expectations equation as well as all regressor of the relevant endogenous reduced form equation<sup>10</sup>. A final characteristic of the estimator  $\beta_1$  is its lack of uniqueness, originating from the difficulty of choosing appropriate explanatory variables (Klein 1974: 153-154).

The disturbance vector of equation (12) is a composite error that does not yield a scalar covariance matrix  $\sigma^2 I$  (Pagan 1984). This causes the standard OLS formula

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<sup>10</sup>. This is indeed the Two Stage Least Square approach where each instrumental variable is obtained by a reduced form regression.

to deliver an accurate estimate for the variance of  $\beta_2$  but understates the variance of  $\beta_1$  (Hoffman 1991: 52). However, as Cuthbertson et al. (1992: 166) point out, the remedy is straightforward in that  $Z^*_t$  in the estimated equation is replaced by the actual value  $Z$  when the error terms are computed. The latter are then used to estimate  $\sigma^2$  and the estimators variances.

#### **3.4.1.1.2. Further Complications**

The previous discussion has assumed that the error term  $v_t$  shows no sign of possible autocorrelation. However, there are two instances<sup>11</sup>, where this assumption is violated (Cuthbertson et al. 1992:167).

The first one is the case of multiple period expectations. In the above case, this would imply that not only  $Z^e_t$  enters into the function but also for example  $Z^e_{t+1}$  and  $Z^e_{t+2}$ . After the actual values have been substituted, the resulting error term will follow an MA(1) process. The conventional formula for the variance of IV estimators is therefore incorrect. However, Hansen and Hodrick (as referred to by Cuthbertson et al. 1992:68-169) have suggested a correction to the formula of the estimator variances. This approach is as follows:

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<sup>11</sup>. None of these instances have occurred during actual model specification and estimation of this study's model.



1. Derive coefficient estimates in the usual fashion through the application of the IV method.
2. Use the estimates to determine the error vector (utilise actual values and not IV estimates in the error predictions)
3. Estimate the correlation coefficient and define the variance covariance matrix accordingly ( $\sigma^2\Omega$ ) ( $\sigma^2$  is estimated by using errors from 2)
4. Modify the formula for the estimator variances and derive estimates<sup>12</sup>

The second case is the conventional problem of serially correlated structural error terms which results in asymptotically less efficient estimators as the serial correlation is ignored. Applying the conventional Cochrane-Orcutt transformation will eliminate the structural correlation but introduce other serial correlation namely a MA(1) process (see McCallum (1979:67-68) for illustration). The following approach is applicable in this regard:

1. Apply the IV method to derive consistent estimates of the coefficients and hence the error term.

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<sup>12</sup>. The conventional formula  $(X'X)^{-1}X'\sigma^2 I_n X(X'X)^{-1}$  or  $\sigma^2(X'X)^{-1}$  becomes  $\sigma^2(X'X)^{-1}X'\Omega X(X'X)^{-1}$  where X is the regressor matrix that incorporates the IV estimates.

2. Utilise the error term of (1) to estimate the Markoff parameter (autocorrelation coefficient).
3. Utilise parameter of (2) to transform variables (original variables - in line with Cochrane-Orcutt transformation)
4. Shift the regressors of the instrumental equation back in time (t-2) to ensure asymptotical independence from the error term and get renewed instrumental forecasts and original coefficient estimates
5. Derive new error terms (using actual values) and determine the variance covariance matrix
6. Determine estimator variances<sup>13</sup>

#### **3.4.1.2. How does IV Address Policy Changes ?**

Concerning RATEX, the IV approach gives empirical meaning to the concept that individuals utilise all available information when forming expectations through an appropriate specification of the instrumental equation. For expectations of the policy instrument, the authorities' policy rule can be used as a basis for choosing instrumental regressors. Given, however, the rationality of individuals, other variables could also be included <sup>14</sup>. However, the IV approach applies only to

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<sup>13</sup>. The formula will be identical to the one derived in the first case. X is based on step 3.



endogenous variables and the policy instrument. With regard to expectations of exogenous variables, an ARMA process will be utilised for modelling<sup>15</sup>. From the latter, the IV can then be derived. However, a necessary requirement for consistency is that no Granger causality exists between the exogenous regressor and other dependent variables (Cuthbertson et al. 1992:167). The following summary can be given with regard to the estimation of RATEX variables:

Expectations concerning **ENDOGENOUS VARIABLES** : IV approach where all predetermined variables in the structural equation are utilised to ensure consistency plus any additional variables (from the corresponding reduced form equation) to ensure RATEX.

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<sup>14</sup>. If the time series in question are integrated of order one, a necessary criterion to ensure proper specification of the instrumental equation is cointegration, as any deviation of the instrumental variable (expectation) from its actual value should be temporary / stationary. The concept of cointegration can also give a solution to the problem regarding the costs of information acquisition. Should the costs of ensuring an uncorrelated error term be substantial i.e. a large number of additional variables would have to be incorporated, cointegration could be considered as sufficient for RATEX as any long term deviations are prevented. This is discussed further in Chapter VII.

<sup>15</sup>. Given that these variables are exogenous, RATEX cannot be based on an underlying process. Consequently, the individual has to rely solely on past values. With regard to the modelling of ARMA processes, this involves the same steps as with conventional econometrics namely identification, estimation and evaluation. However, before proceeding to apply this methodology, it must first be ensured that the time series are stationary. The first step usually involves the evaluation of the correlogram of the respective time series. In the case of pure autoregressive processes, maximum likelihood or OLS estimation can be utilised for step 2. If the model includes a MA processes, a non-linear technique will have to be used. The third step involves the evaluation of the predicted error terms in the light of desirable white noise properties. For a detailed discussion on all of these steps see Pokorny (1987 : 341-415) or Pindyck and Rubinfeld (1991 : 491-495).



Expectations concerning **POLICY INSTRUMENTS** : IV approach where all predetermined variables in the equation are utilised to ensure consistency as well as all remaining variables not yet included with regard to the relevant policy rule.

Expectations concerning **EXOGENOUS VARIABLES** : Should no Granger causality prevail between the exogenous variable and other exogenous regressors, the variable will be represented as an ARMA(p,q) process and consistent OLS estimators are possible. In the case of Granger causality, the relevant variables will be incorporated to ensure RATEX and consistency.

The EV method, through the IV approach, allows the structural model to be free of the Lucas critique in that the expectations formations, although reflecting the relationships of the model, are specified and estimated separately to the model. This is of particular importance in the case of RATEX on policy instruments. As discussed above, during estimation, the IV forecast will be considered as proxies for the actual values. However, during policy simulation different assumptions will be made regarding the expectations formation process of the policy instrument in order to address anticipated and unanticipated policies. Thus, the IV equation becomes the expectations process of individuals concerning the policy instrument. The IV approach is also capable of accommodating possibilities with regard to fundamental policy alterations simply through an alteration of the regressors (inclusion of dummy variables) determining the instrumental variables. In this way, all the above mentioned possibilities can be addressed and evaluated in policy simulation through the same structural model.



### **3.4.2. UNIQUENESS AND STABILITY CONSIDERATIONS IN A MODEL SOLVED AND ESTIMATED BY THE EV METHOD**

When the model is solved, the actual values replace the expectations. The uniqueness problem does not arise in that the model does not have to be solved forward. The actual values, which represent the unique path the economy has progressed on, determine the uniqueness of the model. There is no need to evaluate eigenvalues and set terminal conditions so that future expectations can be determined. A similar argument holds with regard to stability. In the Substitution Method, stability requirements had to be met to ensure that forward substitutions will converge to a definite value. With the current approach, the expectations are not solved forward but actual values replace expectations variables. The model is therefore as stable as the economy. The general assumption is that the economy has an inherent tendency towards a general equilibrium. This perception will be reflected in model specification and provided that the data supports the model, the latter will be inherently stable.

A further issue is the importance of a saddlepoint. With the Substitution Method, this is a requirement to avoid that the many possible forward solutions cause an indeterminacy among agents as to which path the economy follows. With regard to the EV method, a saddle point path is imposed explicitly namely the actual path of the economy. Thus, *'With the EV method, the stable [and unique] solution is imposed explicitly since the expected value is replaced by the actual value plus an orthogonal error, and this is the case however far into the future the expectations occurs'* (Blake 1991:50).

The question of a unique convergence path becomes more involved if policy alterations will cause expectations alterations and temporary deviations of the expectations convergence path from its actual path. If a policy alteration is not anticipated, economic agents will forecast an alternative convergence path to the one predicted by the policy maker. Given that the policy is implemented, economic agents will deviate from the actual long term convergence path. This could be interpreted as a bubble, as eventually, economic agents will have to return to the actual path. The problem is that temporarily more than one convergence path could possibly be formulated in that expectations are not confirmed, allowing room for speculation. How will individual agents return to a unique solution path so that a stable solution is again possible ? The answer lies in the way economic agents form their expectations. Any correlation between errors from the actual and expected convergence path will be incorporated in RATEX formation. Thus, any deviation can only persist for a limited number of periods. A unique convergence path is therefore again ensured in that any permanent deviation is not possible within the definition of RATEX. This is true even for weak RATEX as even these expectations will have a tendency to equalise with the structure of the model. Thus, deviations by the auxiliary equations from the actual values will not affect the EV method's property of providing a unique and stable solution.



### 3.4.3. IV AND OTHER ESTIMATION TECHNIQUES

The EV method as an estimation technique for linear RATEX models was originally introduced by Wickens (1982) who argues that this method provides a much less burdensome estimator though at the expense of both full rationality and asymptotic efficiency. The lack of efficiency results from the fact that single equation methods ignore the cross equation RATEX restrictions. He (1982:64) suggests full information method for estimation while the approach chosen in this study is a single equation technique. This approach was chosen not so much because of its simplicity as for the inconclusiveness with regard to the superiority of the other techniques. Hasan (1987) compares in that respect the IV single estimation method with Wickens full information technique on the bases of Monte Carlo experiments. He (1987:314) concludes that ' *the differences in the relative performance of alternative methods were not very pronounced.... superiority of one method over another could not be established. [These results support] the use of the simple single equation method rather than the more complex full information estimators... '.*

In the above discussion, the Hansen-Hodrick procedure was introduced as a possible solution to correlated error terms. Alternatively, one could have made use of the insight provided by Hayashi and Sims (1982) (see, for example Cuthbertson et al. 1992:171). Both of these can be seen as a special application of the Generalised Method of Moments (GMM) as originally introduced by Hansen and Sargent (1982). An alternative technique in the presence of autocorrelated error terms was suggested by Cumby Huizinga and Obstfeld (1983) namely the Two -



Step, Two-Stage Least Square (2S-2SLS) estimator which is asymptotically more efficient than the one derived from the Hansen-Hodrick correction. However, as Cuthbertson et al. (1992:172) point out, in small and moderate samples one cannot say which technique is better as both of their properties rely on asymptotic results.

### **3.5. CONCLUSION**

Broadly defined, there are two approaches to solving a RATEX model containing future expectations namely the Substitution Method and the EV method. Both of these techniques are aimed at the determination of a visible model necessary for estimation. The Substitution Method solves the model for the expectations variables and replaces them accordingly. The EV method simply replaces the expectations variables with the actual variables.

An inherent difficulty with the Substitution Method is the question of uniqueness and stability in the presence of forward looking RATEX. A unique path needs to be determined for each of these RATEX variables as continuous substitution shifts the time horizon further and further. For that series to converge to a detectable path (i.e. the expectations are expressed solely in term of exogenous variables), unstable roots have to be found so that forward substitution is possible. Should there be as many unstable roots as future RATEX, a saddlepath, implying a unique and stable solution, is possible. Should the roots be stable so that only backward solving can provide a visible expression, the difficulty surrounding uniqueness and stability occur in that the future path cannot be traced as it is explosive and non-unique. To overcome this problem, use can be made of terminal conditions,



conditions that will restrict the path of the RATEX variable and in that way make it unique.

Besides the problem of uniqueness and stability, the Substitution Method is unattractive in that it requires nonlinear estimation techniques. It also always represents the strong form of RATEX so that no discrepancy between the expectations process and the model is possible.

The EV method is attractive in that the expectations variable is simply replaced by the actual values. There is no need to define the future path of expectations variables for stability and uniqueness criteria. However, to ensure consistent estimators, an IV approach is necessary as an approximation for the actual value. Once the model is used for policy evaluation, the IV equation governing the policy instrument can be interpreted as the expectations process which allows unanticipated policy modelling.

Given the advantages of the EV method, the study will rely on this technique. For estimation, a single equation IV approach is followed and, should autocorrelated errors prevail, the Hansen-Hodrick technique will be utilised. Although numerous other single and multiple equation estimation techniques have been suggested, no convincing results have yet occurred that would necessitate their consideration.

## **CHAPTER IV: PREVIOUS STUDIES OF MODELS WITH RATIONAL EXPECTATIONS**

### **4.1. INTRODUCTION**

In the previous two Chapters, the theoretical background regarding the Lucas critique and RATEX was given. This Chapter serves the purpose of evaluating how RATEX has been incorporated into models in practice. A number of models will be evaluated and particular emphasis will be placed on the way in which these models are solved i.e. the practical application of the Substitution Method. Most RATEX models are non-linear, an aspect necessitating alternative solution techniques to the linear Substitution Method outlined in Chapter III. However, these techniques are synonymous with the Substitution Method and can be equally well employed in the case of linear models as will become apparent from the discussion below.

A large number of macroeconomic models with the distinct aim of incorporating RATEX have been estimated in previous years. The most prominent of them are the FAIR model of the US, the LBS, LPL, HM Treasury and NIESR models of the United Kingdom, the QMED model of Finland and the MORKMON II model of the Dutch economy (Bikker et al. 1994)<sup>1</sup>. The task of this section is not to provide

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<sup>1</sup>. Numerous multicountry models have also adopted RATEX specifications such as the MULTIMOD Mark III Model of the IMF (Laxton, Isard, Faruquee Prasard and Turtelboom: 1998). For a comparison of earlier multicountry models, see Bikker, Van Els and Hemerijck (1993). Given that the focus of this study falls on a single country model, these models are not further discussed although reference is given where relevant.



a detailed evaluation of each model. Rather, the focus falls on identifying key characteristics (such as the type of RATES variables) of each model. This will be discussed in Section 3.3. It is intended to provide the background to the model specification in Section B as well as highlight some of the unique features of the proposed model, particularly with regard to policy evaluation. Section 3.4 is a critical evaluation of the solution techniques and model specifications in the light of policy evaluations. All of the studied models can be assessed on grounds of the characteristics of the Substitution Method. However, before this can be accomplished, a brief summary of the estimation techniques actually employed in solving these models is required. Section 3.2 serves that purpose.

## **4.2. SOLUTION METHODS IN PRACTICE**

The theoretical discussion of Chapter III illustrated two options when solving a RATES model namely the Substitution Method and the EV method. Hall and Henry (1985:65-66) classify these two as Consistent and Backward solutions respectively<sup>2</sup>. With regard to the Substitution Method, three techniques have been applied in practice namely the Extended Path Method by Fair and Taylor (1983) (also referred to as the Anderson and Taylor iterative technique), the Penalty-Function of Holly and Zarrop (1983) and an approach outlined by Hall (1985)<sup>3</sup>.

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<sup>2</sup>. In the context of Chapter III, classifying the EV method as backward is misleading in that this technique is very well capable of taking the structure of the model into account. This will be further explained below.

<sup>3</sup>. For a broad comparison and discussion of these three techniques, see Cuthbertson et al. (1992:235-238).

These techniques are all aimed at non-linear models but can also easily be applied to linear models. All of them ensure that expectations variables and model forecasts are equivalent, therefore deriving strong RATES.

#### **4.2.1. THE FAIR-TAYLOR EXTENDED PATH METHOD**

This approach is the most common iterative solution technique used. The model is solved for a given set of expectations, which are initially exogenous. In the next step, the expectations are updated by some fraction of the difference between expectations and actual model solutions. The model is then solved for the moderated expectation vector and checked for convergence of expectations and solutions. This process continues until convergence has occurred. The Extended Path Method can be described in five steps (Fair and Taylor (1983:1171-1172), Hall (1985:158):

1. Determine the time span for which expectations beyond the solution period is required (call it  $k$ ). Give initial values<sup>4</sup> to the expectation variables.
2. Solve the model.
3. For each expectation variable and each period, compute the difference between the model's solutions and the corresponding expectation variables. If this difference is outside a pre-specified tolerance level (convergence has

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<sup>4</sup>. In practice, these values are often obtained through an IV estimation. This is discussed below.



not occurred) go to step 2 and utilise the new solutions as expectation guesses. If convergence has occurred, proceed to step 4.

4. Repeat steps 1 to 3, replacing  $k$  by  $k+1$ . Compare the expectation values under  $k$  with those of  $k+1$ . If convergence has not occurred, repeat steps 1 to 4. If it has occurred, proceed to step 5.
5. Solve the model using the expectations of step 4. These expectations will be model consistent within a given tolerance level.

The Extended Path Method aims at the equalisation of model forecasts with expectations and in that way ensures consistent expectations. Consequently, it is synonymous with the Substitution Method applied in the linear case where the model is solved for the expectation values. The Extended Path Method is applicable to the linear as well as non-linear case and Fair and Taylor (1983: 1177-1180) prove that in the linear case, the Extended Path Method indeed provides the solution of the Substitution Method.

Hall (1985: 158) maintains that there is a high chance of non-convergence and that the approach is rather inefficient as the model is solved for full Gauss-Seidel<sup>5</sup> convergence at each step of the algorithm.

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<sup>5</sup>. The Gauss-Seidel technique is the most popular method to solve non-linear models and the Extended Path Method is nothing but an extended application of this technique. For an explanation on Gauss-Seidel see Fair (1984: 249-252).

#### 4.2.2. HOLLY AND ZARROP'S PENALTY-FUNCTION-METHOD

Another solution technique is the Penalty-Function Method suggested by Holly and Zarrop (1983). This approach formulates the problem in an optimal control framework. The expectation variables are the instruments and the targets are the  $t-1$  (where  $t$  is the solution period) consistency conditions for each expectation variable as well as the terminal conditions in period  $t$ . The objective function that needs to be minimised subject to the model itself is given by the deviations of expectations from actual values:

$$C = [Y_e - Y]' \Omega [Y_e - Y]$$

According to Hall (1985: 157) this technique is fairly reliable in that should a solution to the model exist, this approach will generally find it, but it has the drawback that it limits the number of expectation terms which can appear in the model as the control problem quickly becomes intractable with increased control variables. Westaway and Whittaker (1986:13) also maintain that roots near unity present no particular problem. As explained below, such roots can become a serious problem in deriving a unique solution with a conventional iterative technique.

#### 4.2.3. HALL'S APPROACH

Finally there is an iterative technique outlined by Hall (1985). Hall (1985: 158) starts out by regarding the solution of an  $n$  equation model over  $t$  periods as if it



was a set of  $n \times t$  simultaneous equations in a static framework. These equations are then simply solved through the application of the Gauss-Seidel algorithm. Hall (1985:158-159) summarises his approach in three steps:

1. Assign initial values to the expectations variables
2. Solve each equation for each time period
3. If convergence within a given tolerance has occurred over all periods then stop. Otherwise, replace initial values with the new solutions and repeat the process.

It can be seen that this technique is nothing but Gauss-Seidel applied to all equations for all time periods.

#### **4.3. SOLUTION METHODS AND TERMINAL CONDITIONS**

The initial expectation values in the above iterations are often derived from an instrumental variable estimation. Thus, as an initial approximation for expectations, the EV method is employed. However, this technique is only utilised in order to solve the model initially and derive, via one of the above mentioned techniques, the strong RATES form. Similarly, the weak form of RATES is used during estimation in the sense that only once the estimated model is simulated, can model consistent (strong) expectations be derived. The above mentioned approaches have therefore two components:

1. Derive initial expectations and estimate the model through, for example, IV estimation on the expectation variables.
2. Solve the estimated model to derive a model consistent expectation vector<sup>6</sup>.

This approach is therefore similar to the EV method proposed in the previous Chapter in that a distinction is made between expectations for the purpose of estimation and for the purpose of simulation. Westaway (1992: 87) states it as follows: *'The strong form of RATEX is not really relevant in an estimation context since most applied work relies on the approach by McCallum (1976) and Wickens (1982) which only requires that agents make no systematic errors in forming expectations, an assumption known as the weak form rational expectations assumption. Once these equations are incorporated within a large macroeconomic model, however, the conventional assumption in using the model for simulations or in conducting policy analysis is that period by period model consistent expectations are assumed'*. However, this approach differs from the one suggested in this study in that a solution technique is necessary to derive strong RATEX whereas in the proposed technique, the IV equation, being a reflection of model characteristics, gets redefined as the expectation process during simulations.

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<sup>6</sup>. These two aspects show that the Substitution Method outlined in the previous Chapter has been reversed. In Chapter III, the model was solved to derive 'visible' regressors in order to allow estimation. Now, the model is first estimated to allow policy simulations to occur.



The solving technique used most often in the context of current linear and non-linear RATES models is the Fair and Taylor approach<sup>7</sup>. As outlined in Chapter III, the Substitution Method does not ensure uniqueness nor the stability of its solution. The Fair and Taylor (or substitution) approach implies that structural equations have variables that are the solutions of the model in future periods. Should the model be solved or simulated over  $T$  periods, equations referring to the end period will require model solutions that fall outside the specified time span of solving. Consequently, to ensure a unique model solution, values (or equations specifying values) need to be determined for the expectation values outside the solution period. As outlined in Chapter III, these values are referred to as terminal values.

In Chapter III, it was shown that provided certain conditions regarding eigenvalues are fulfilled, forward expectations will converge in infinity. The infinite state or infinite convergence path can for example refer to an equilibrium state or a steady growth rate. These properties, referring to the infinite long run nature of a variable, are also known as transversality conditions (Ireland and Wren-Lewis 1989:91). Consequently, terminal conditions need to be based on transversality conditions so that expectations at the end of the solution period are indeed on the infinite solution path. In this way, the finite solution period  $T$  will

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<sup>7</sup>. One exception is the MULTIMOD Mark III model, where the Fair and Taylor approach was replaced with one which suggest significant savings of time. This solution technique is not based on the Gauss Seidel algorithm. See Laxton et al. (1998: 19-22) for a discussion.



be equal to the infinite solution for that period without having to drive the models equations to infinity (Hall and Herbert 1986:66).

The nature of the transversality conditions depends on the assumptions and properties of the model. Thus, should a market clearing model be used, equilibrium conditions should be used as terminal conditions while using constant growth rates as terminal conditions indicates an infinite time solution that reflects steady growth rates. Consequently, depending on the respective model properties and hence assumed transversality conditions, different terminal values become appropriate<sup>8</sup>. However, as Ireland and Wren-Lewis (1989) point out with the help of the NIESR 11.2 model, terminal conditions can have a major impact on model properties. Should for example, a model require a time period in excess of the solving period to return to equilibrium, the terminal conditions would enforce an equilibrium state prior to the actual equilibrium, thereby distorting the dynamics and properties of the model. One possible precaution which is generally applied to this problem is to change the terminal date and compare the different model solutions. Ideally, those results should correspond, indicating that the terminal values have no influence on model properties.

The impact that a terminal condition has on the model solution and its dynamics depends on the forward looking root of the relevant expectation variable. The closer that root is to unity, the greater the influence of future values and hence the

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<sup>8</sup>. For example, in the MULTIMOD III model, the steady state terminal conditions rely heavily on the assumptions about the steady state level of interest rates and growth. In the base line level, the steady state real interest rate on short term government debt is set at an imposed level of 4.25



terminal condition. As was further shown in Chapter III, an additional implication of a close unit root is that the current impact of future expectations may not converge. Consequently, no unique solution can be derived as the full influence of future expectations cannot be modelled. Indeed, this is nothing but restating the Blanchard and Kahn (1980) criterion for a saddle path discussed in Chapter III.

The following discussion will provide an overview on current RATEX models. Particular emphasis is placed on the solution method utilised for each model as well as the terminal conditions employed. General characteristics of each model are also provided.

#### **4.4. KEY FEATURES OF SINGLE COUNTRY RATEX MODELS**

##### **4.4.1. THE FAIR MODEL**

The Fair model is a non-linear model of the US economy consisting of 128 equations of which 30 are stochastic. These equations cover the household, firm, financial, foreign, federal government and state and local government sectors. In an article in 1979, Fair modified the initial model by introducing RATEX into the bond and stock markets<sup>9</sup>. With regard to the bond market, the model is based on the expectations theory of the term structure of interest rates. This implies that the return from an  $n$  period security should be equal to the expected return of one

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per cent (Laxton et al 1998:21).

<sup>9</sup>. For a full discussion on the Fair model, see Fair (1984: 103-152, 435-442). With regard to the inclusion of RATEX, see Fair (1979) or Fair (1984: 390-399).

period securities over  $n$  periods<sup>10</sup>. With regard to the stock market, stock prices are modelled as the present value of all expected future after tax cash flows (or net profits) (Fair 1979: 542-545). Consequently, the FAIR model has two RATEX variables, namely future short term interest rates and future profits:

**Table 4.1: RATEX in the FAIR Model**

EQUATIONS	RATEX VARIABLE
Long term rate	Short term interest rate
Share prices	Net profits

Simulation results of the modified model are provided by Fair (1979: 548-549)<sup>11</sup>. In these simulations, the terminal condition was set to be the average of the last eight expected values within the data period. The total simulation period stretched over 22 quarters, a time period sufficiently long to ensure that the first twelve quarters are independent of the terminal values. This conclusion is supported by varying the simulation period and comparing the simulated results. The solution method has been the extended-path-method.

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<sup>10</sup>. For an elementary discussion on the expectation theory, see Gowland (1985:184 - 192).

<sup>11</sup>. Further simulations are provided by Fair (1984:392-399). These simulations refer to anticipated as well as unanticipated policy changes. The model is solved over 12 quarters only so that no terminal conditions were necessary as adequate future variables were available.



#### 4.4.2. THE LONDON BUSINESS SCHOOL MODEL<sup>12</sup>

The London Business School (LBS) model is a non-linear quarterly model of the UK economy primarily used for forecasting. It consists of 339 stochastic equations and has three RATEX variables, namely the price of guilds, the price of equities and the price of overseas assets. All these variables are expressed as indexes and expectations are all one period into the future. All RATEX variables are found in the equations governing the financial sector and more specific, in the asset demand equations where price expectations reflect expected capital gains. The financial sector is based on market clearing under RATEX with three prices namely guilds, equities and the exchange rate. However, by the end of the 1980's the LBS abandoned this indirect approach and directly modelled the exchange rate.

**Table 4.2: RATEX in the LBS Model**

EQUATION	RATEX VARIABLE
Asset demand. For a detailed exposition of the asset demand equations and their expectation variables, see Budd et al. (1984:393-394).	Price of guilds, equities and overseas assets

With regard to the model itself, the following summary statements can be made. The consumption function is a combination of the liquidity and wealth approach.

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<sup>12</sup>. The proceeding discussion focuses on the LBL model as published by Budd et al. (1984). There is, however, a new London Business School model of the UK economy in which RATEX has been replaced by a learning approach. For a descriptive summary of this new model, see Allen, Hall and Nixon (1994).

The general form of the export function includes the ratio of domestic to world prices as well as world trade while imports are treated in a similar fashion with domestic output replacing world trade. The exchange rate is determined by a number of structural asset demand equations and is therefore based on the portfolio approach. The general price equation is based on a mark-up strategy, with unit labour costs and import prices primary determinants.

The model is specified by the General-to-Specific procedure<sup>13</sup>. Estimation was carried out with the help of IV procedure. The model is solved by applying Holly and Zarrod's Penalty-Function Method.

#### **4.4.3. THE LIVERPOOL MACROECONOMIC MODEL**

The Liverpool Macroeconomic (LPL) model is a new classical model in that it is a combination of market clearing (markets clear in each annual period)<sup>14</sup> and RATEX. Since 1984, the model has remained largely unchanged. However, in 1990, it has changed from an annual to a quarterly model. It is non-linear and emphasises the role of stocks rather than flows as seen, for example, in the specification of consumption which includes a wealth component. In the LPL model, four RATEX variables are present:

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<sup>13</sup>. For a detailed discussion on this procedure, see Darnell and Evans 1990:77-94).

<sup>14</sup>. The model assumes that continuous market clearing occurs in the non-union sector. However, given nominal one year wage contracts, changes in the real wage and consequently output fluctuations do occur in other goods markets. The latter are the result of the union's behaviour



**Table 4.3: RATEX in the LPL Model**

EQUATION	RATEX VARIABLE
Non-durable consumption	Capacity utilisation
Nominal short and long term interest rates	Inflation
Equilibrium government Spending	Real debt interest
Real short and long run interest rates	Real exchange rate

In its stylised version, the model consists of seven equations (the full model consists of 27 (11 stochastic) equations) that reflect classical economics (Minford, Marwaha, Matthews and Sprague 1984: 25-26, 40). The supply equation includes an equilibrium or natural level of output and hence unemployment. Domestic interest rates are endogenous with the real rates given by the efficient market hypothesis. It links domestic real interest rates to the real exchange rate and foreign real interest rates by ensuring that real interest rate differentials are offset by real exchange rate movements. The demand for money is determined by real GDP, nominal interest rates and real financial assets while the money supply (in the long run) depends only on the public sector borrowing requirement as the latter determines long term inflation expectations. In line with classic/monetarist doctrine, the money supply is considered as a policy instrument. Other instruments, such as government expenditure or taxes are used for fiscal policy.

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and not the outcome of expectations errors by workers as could be speculated under adaptive expectations.

The model is solved by making use of Fair and Taylor's Extended-Path Method. Thus, after estimation, the computer algorithm guesses an initial expectation and solves the model accordingly. In the second step, the expectation of this initial simulation are taken as expectations and the process continues until convergence of expectations and forecasts is achieved. To ensure that the final path of the algorithm is unique and consistent, the forecasts and expectations variables are subject to equilibrium terminal conditions at the end of the forecasting horizon<sup>15</sup>. Other ways of solving are also suggested<sup>16</sup>, however, they are all based on the rational of equalising model forecasts with expectations (Minford et al. 1984:38-39). The results published by Minford et al. (1984) are based on single equation IV estimation by utilising either least square or limited information maximum likelihood.

#### **4.4.4. THE NATIONAL INSTITUTE'S ECONOMETRIC MODEL**

In 1985, the non-linear, quarterly model of the National Institute (NIESR model 8) has been modified to incorporate RATEX (Hall and Herbert:1985). RATEX variables were introduced in the employment, stockbuilding, and investment

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<sup>15</sup>. For a discussion of the LPL's terminal conditions and the model's sensitivity to these conditions, see Whitley (1994:159-163).

<sup>16</sup>. One approach has been the utilisation of 2SLS to estimate the model initially. The resulting model forecasts are then re-substituted and the model is solved for a second time. Minford et al. (1984:39) maintain that this process can be repeated until full convergence has occurred. However, they question the additional gain from repeating the process. Alternatively McCallum's IV approach has also been suggested as an estimation technique.



sector as well as in the wage formation, exchange rate and demand for money sectors. The following summary can be given :

**Table 4.4: RATEX in the NIESR Model 8**

EQUATION	RATEX VARIABLE
Employment	Output, real wages, real prices
Stockbuilding	Output (current and future periods)
Investment	Output
Wages	Change in prices in the next period. The wage equation was estimated by utilising cointegration and a resulting error correction model, see Hall and Henry (1984:63-64).
Real effective exchange rate	Real effective exchange rate in following period
Demand for money (M1)	Prices, output, interest rate. The model consists of a long run demand function (with prices, output and interest rates as determinants) and deviations from expectations.

In model 11 (1988), equations regarding employment stock and investment were estimated by utilising actual data (from surveys) on output expectations. In model 11.4 (1989), consumer prices were modified to be also forward looking <sup>17</sup>. With regard to uniqueness, the model has four optional terminal conditions (Hall and Herbert 1986:66-67):

1. Setting terminal conditions to exogenous data variables.
2. Setting terminal conditions so that they lie on the previous years' growth path.

<sup>17</sup>. See Wren-Lewis (1988), (1989) for additional changes to the model.

3. Setting terminal values so that the levels of the variables are projected flat.
4. Setting terminal values to project a constant rate of growth from the final quarter of the solution period.

All simulations by Hall and Herbert (1986: 70-73) utilised the fourth option on grounds that the solution path is not substantially affected by the terminal date. This conclusion is supported by Ireland and Wren-Lewis (1989: 91) who maintain that '*for most of the forward looking variables in the Institutes' model [version 11] the forward looking root is well below one; that is, the current value of the forward looking variable will only depend on events in the near future. In such cases, rate of growth terminal conditions appear to be fairly robust to changes in the terminal date*'. However, one exception is the exchange rate equation where the forward looking root is close to unity. Only after a simulation over a 12 year period does the initial jump in the exchange rate tend to become unaffected by the terminal date (see Ireland and Wren-Lewis 1989: 92). The solving technique utilised for NIESR 8 is based on Hall's approach and the estimation technique is a two-step IV approach<sup>18</sup>.

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<sup>18</sup>. The specific technique is outlined by Hall (1984).



#### 4.4.5. THE HM TREASURY MODEL

The Treasury Model is a quarterly, non-linear model of 880 endogenous variables of which about 500 are explained by behavioural equations<sup>19</sup>. It is the largest of the quarterly models considered here, a factor attributable not only to greater disaggregation but also to the detailed treatment of public sector transactions. It reflects a standard expenditure income framework and treats nominal interest rates as exogenous. Prices are predominantly modelled as a mark-up over costs.

In the old model specification, no provision was made for RATEX, rather these are introduced as an alternative assumption during simulation. Thus, model consistent expectations are derived by using a different solution technique. The model is solved by utilising the optimal control technique of Holly and Zarrop (1983). The HM model has four explicit expectations variables referring to the exchange rate, capital gains, manufacturing output and prices. However, in their discussion of consistent expectations, Westaway and Whittaker (1986) consider only the first three of these variables while during actual simulation, only the exchange rate and capital gains (or percentage change in capital value) are evaluated.

As was the case in the old model, the new model uses a combination of adaptive expectations, directly measured expectations and RATEX. Except for in the case

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of asset markets, particularly the exchange rate and the long interest rate, all expectations are not model consistent (Chan, Savage and Whittaker 1995: 11-12)

**Table 4.5: RATEX in the HM Treasury Model**

EQUATION	RATEX VARIABLE
Exchange rate	Exchange rate
Long rates (yield on portfolio investment)	Capital gains

For the exchange rate, a terminal condition of zero change is used which implies that the exchange rate is assumed to be constant after the terminal date. The terminal condition for capital gains is set to be zero, implying that short and long term interest rates are equal at and after the terminal date (Westaway and Whittaker 1986:17-18). Similarly to the case of the exchange rate in the NIESR model, Westaway and Whittaker report that the unstable roots associated with the two expectation variables are fairly close to unity, again implying that future events and consequently the terminal conditions, have a major impact on current values.

The reported simulations by Melliss (1988:255) were carried out over nine years to ensure that the terminal date does not exert any influence on model properties for the first five years. To test more specifically for the sensitivity of the exchange rate to terminal values, Westaway and Whittaker (1986:20-23) carried out simulations with different terminal conditions. They concluded that a solution period of twelve years is required to obtain simulation results for the first few

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<sup>19</sup>. These model characteristics refer to the Model in 1986 as published by Melliss (1988). The new HM model has been downscaled and includes only 357 equations excluding the fiscal block (Chan, Savage and Whittaker 1995: 5).



years that are independent to the terminal assumptions. Simulation results of the new model reported by Chan, Savage and Whittaker (1995:58-68) also show that the model's solution is rather sensitive to the specification of expectations formation.

#### **4.4.6. THE MORKMON II MODEL**

MORKMON II is a quarterly model of the Dutch economy consisting of 160 behavioural equations of which 100 describe the monetary sector. The model aims at distinguishing long-run economic relationships and short-term adjustment dynamics by utilising the error-correction mechanism. The model published by Fase et al. (1992) makes no provision for RATEX. However Bikker et al. (1993) discuss the introduction of RATEX into the model as well as resulting simulation properties under the assumption of anticipated and unanticipated policy responses. The underlying methodology is similar to the one applied to all other models.

RATEX was introduced in seven equations which were re-estimated by the IV method. The solution method employed is Fair and Taylor's Extended-Path Method. Terminal conditions were derived from the steady state properties of the model. To ensure that terminal conditions exert no influence on model properties, the terminal date is set twice as far into the future as the horizon of the simulation period. According to Bikker et al.(1993: 307), this measure ensured consistent results when different terminal dates were tested. The following equations contain RATEX variables (Bikker et al. 1993: 305-306):

**Table 4.6: RATEX in the MORKMON II Model**

EQUATION	RATEX VARIABLE
Private consumption	Real disposable wage and transfer income, other real income, inflation
Wages	Inflation
Investment in dwellings	Capital market rate
Exchange rate	Short term interest rate
Money market rate	Exchange rate
Stock exchange index	Capital market rate and dividends
Demand for long term funds by business	Long term interest rate

In their study of simulation properties, Bikker et al. (1993: 312) conclude that the inclusion of RATEX variables has only lead to little change, a factor they ascribe to the exogenous interest rate. It is primarily in the short term, where RATEX variables exercise their biggest influence in comparison to Adaptive Expectations.

#### **4.4.7. THE QMED MODEL OF THE FINNISH ECONOMY**

QMED is a small (14 main behavioural equations), annual, linear model of the Finish economy<sup>20</sup>. Two RATEX variables are included, namely inflation and income. They are only one period forward looking and are found in the following equations:

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<sup>20</sup>. For a summary of the equations, see Lahti and Viren (1988: 348).



**Table 4.7: RATEX in the QMED Model**

EQUATION	RATEX
Private consumption	Inflation and real disposable income
Housing investment	Real disposable income and inflation (via real interest rates)
Wages	Inflation

The model is first estimated by OLS (IV) after which the model's forecasts form the instruments for endogenous and expectation variables. In line with Fair and Taylor's Extended-Path Method, substitution continuous until convergence has occurred.

Most variables of QMED are included in their first difference form. Private consumption prices are determined solely by changes in the wage rate as well as changes in the lagged level of import prices. Prices are therefore considered as a mark-up over costs. The long term interest rate (Government bond yield) is a function of prices, real outstanding government debt and the discount rate. The interest rate (discount rate or money market rate) is seen as a policy instrument and respective simulations are published by Lahti and Viren (1988). Similar to Bikker et al. (1993), they (1988:352) conclude that the major effect of RATEX lies in the short term when compared to autoregressive expectations.

**TABLE 4.8: Summary of Published Simulations of Discussed Models**

MODEL	AUTHOR
FAIR	Fair (1979, 1984)
LBS	Budd et al. (1984), Whitley (1994)
NIESR	Hall and Herbert (1986); Ireland and Wren-Lewis (1989); Whitley (1994); Wren-Lewis (1988); Hall (1987); Blake and Westaway (1995)
LPL	Minford et al. (1984); Whitley (1994)
HM TREASURY	Melliss (1988), Westaway and Whittaker (1986)
MORKMON II	Bikker et al. (1993); Fase et al. (1992). The simulations by Fase et al. (1992) are not based on the RATEX version of Morkmon II.-
QMED	Lahti and Viren (1988)

For a comparative evaluation of the simulation properties of the HMT, LPL, LBS and NIESR models see Fisher, Tanna, Turner, Wallis and Whitley (1989) and (1992), Church, Mitchell, Turner, Wallis and Whitley (1991) as well as Whitley (1994).

#### **4.5. PREVIOUS STUDIES UTILISING ALTERNATIVE SOLUTION TECHNIQUES**

There are numerous studies that have utilised alternative solution techniques to the ones discussed so far. These studies also use the term rational expectations in a context that does not treat rational expectations and model consistent expectations as interchangeable. The following discussion highlights these aspects by briefly mentioning a number of studies and compares them to the suggested solution technique and the way in which the term rational expectations is used in the current study.



#### 4.5.1. ALTERNATIVE SOLUTION TECHNIQUES AND APPLICATIONS OF THE CONCEPT OF RATIONAL EXPECTATIONS

Crockett (1995) uses the concept of rational expectations to derive inflation expectations in a model testing the validity of Fisher's hypothesis which relates ex ante real returns to the nominal interest rate and the market's expectation of inflation. Crockett (1995: 3-4) maintains that *'in specifying the rational expectations forecast, we make the standard assumption that inflation is one of several macroeconomic variables jointly determined each period by a system of stochastic structural equations. We assume that inflation can be expressed in reduced form as a function of past realisations of system variables and contemporaneous values of exogenous variables plus an uncorrelated disturbance term'*<sup>21</sup>. This assumption effectively eliminates the forward solution problem and can be made as the model is not disaggregated. In the current study, expectations are based on a similar assumption. However, because of the size of the model, such an assumption can lead to not fully model consistent expectations for certain variables. As pointed out in Chapter II, the focus therefore falls on weak RATEX.

In an earlier study, Woglom (1979) built a simple rational expectations model for monetary policy evaluation. The model consists of three structural equations explaining real output, the price level and the nominal money stock. One period

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<sup>21</sup>. She (1995:4) suggests that expectations of future exogenous variables may be predicted from anticipatory data. For, example, government expenditure may be estimated from budget data while investment and consumption may be predicted from published surveys of spending plans.



ahead expectations are formed on the price level. As a result, Woglom (1979:94) derives the expectations process from the structural model as a function of lagged disturbance terms only. This is possible, again, due to the simplicity of the model and the fact that expectations are formed on current prices only. Of interest is the fact that the expectation process is specified as an equation and the coefficients are combinations of the structural model's coefficients. An explicit expectations formation process is identified and estimated which is again in line with the current approach.

Nadeem, Haque, Lahiri and Montiel (1990) build a macroeconometric model for developing countries with RATEX. They (1990: 549) utilise the EV method as an estimation technique. However, no attempt is made to solve the model.

Buiter (1980) built a standard IS-LM model with instantaneous market clearing, perfect foresight and RATEX. From the structural model, he derives expected prices in period  $t$  to be a function of lagged prices, capacity output and the expected nominal money supply in period  $t$ . He derives this specification from the structural model (Buiter 1980:802). He does not go on expressing the expectation process as a reduced form with expected money supply having been eliminated but replaces the expectation in a later Section with a feedback rule, which relates money stock to past disturbances. This suggests that RATEX is not interpreted as model consistent expectations. Indeed, Buiter (1980:802) refers to RATEX as minimum mean square error forecasts. Such a specification could differ to model consistent forecasts.



Alexander (1990) built a 9-equation model of the German economy to analyse fiscal policy under RATEX. Expectations are formed on the current inflation rate. The expectation process is obtained by deriving a reduced equation for the expectation variable. Given that expectations are formed again for the current period only, the reduced form contains only lagged endogenous or exogenous variables. The expected values are estimated using Box Jenkins procedures (Alexander 1990: 445-450). Thus an ARIMA process is specified as the expectations process. Similar to the current study, expectations on tax rates are estimated by utilising the actual values.

Atesoglu (1988) build a rational expectation model of price and wage inflation for West Germany. RATEX were formed on the price level in the current period. Atesoglu (1988: 481-482) derives an expectations formation process where the expected price level in period  $t$  is a function of expected money demand growth in period  $t$  and interest rates in period  $t-1$ . The expected money growth is the difference between actual and unanticipated money demand. In the model a demand for money function is specified as a function of current prices, real income and interest rates. To determine the unanticipated money supply (which, in the current study, is the expectations error between model solutions and the forecast of expectations processes given non-model consistent expectations), he specifies a second function (policy rule) for the money supply with the error term being the unanticipated rate. This expectation is therefore not model consistent and is derived from various lagged variables only. Therefore, the process upon which expectations are based and the model's structure bare no resemblance.



However, the expectations are seen as rational as the error term, is defined as the unanticipated component.

#### **4.5.2. THE APPROPRIATENESS OF THE CURRENT APPLICATION OF RATIONAL EXPECTATIONS**

All models are able to derive reduced form expectation processes without forward solution problems. This is achieved either by making assumptions about these variables that are forward looking or they are entirely exogenous to the model. In this way, they are able to identify and solve the expectation process and still comply with fully model consistent expectations. Thus, an expectations equation can be fully derived from the structural coefficients. In the current study, this is possible for the policy instrument, which is essential for addressing the Lucas critique and a number of further expectations. However, it is not possible to derive the reduced form for all expectations processes, as this would entail the forward solution problem in that expectations for period  $t+1$  depend on expectations for  $t+2$ .

In the current study, the expectations processes are estimated. However, the estimated coefficients are functions of the structural equations and could thus be solved for from the structural equations. This is the approach of a number of studies. The reason why the expectations processes are estimated rather than solved from the reduced form is to address those expectations processes for which a reduced form cannot be derived without solving forward on a solution path. As outlined, the problems surrounding a stable solution path, the need for terminal



conditions and the information set required by economic agents to derive strong RATEX expectations makes this approach unattractive. The studies mentioned above do not have this problem, as the econometric model is not as detailed so that expectations are a function of future exogenous variables rather than endogenous variables. By estimating an expectation process not fully derivable from the structural model, the resulting expectations is not fully model consistent. An expectations error is therefore incurred. However, provided that the expectations are uncorrelated with all the information set in period  $t-1$ , weak rational expectations still hold. Furthermore, as outlined, the forward looking solution process also allows for a margin of error. The Lucas critique is still addressed with the suggested approach as expectations on the policy instrument are fully model consistent in the current study so that expectations will always equal the structural model's solution and all coefficients of the reaction function are identified in the expectation process.

The expectation errors of the expectation processes not fully model consistent can be seen as unanticipated errors in line with Atesoglu's study. Provided there is no autocorrelation, they can still be classified as rational according to Buiter's definition of minimum least square but also on theoretical grounds given the fact that the expectation processes are based on economic theory and at least partly on the model's structure. Such unanticipated components must not be confused with an unanticipated policy expectation. Given that these expectations are model consistent, unanticipated expectations can only come about from a policy simulation where an unanticipated policy shock has been introduced.



In order to ensure rational expectations, tests for rational expectations as they have been applied in numerous studies are carried out. These are discussed and applied in Chapter VII.

#### **4.6. POLICY MODELLING WITH EXISTING RATEX MODELS - A COMMENT ON THE CONVENTIONAL METHODOLOGY OF SOLVING RATEX MODELS**

In the case of backward looking models, no need for distinguishing anticipated from unanticipated shocks arises. Any shock is unanticipated as expectations are solely based on past experiences. As indicated in Chapter II, a key aspect of RATEX is the distinction between anticipated and unanticipated policies, an issue arising from the forward looking nature of these expectations. If individuals form forward looking RATEX and in that way anticipate a future change in a variable, their behaviour may alter in response to their expectations which results in a behavioural change prior to the actual shock.

##### **4.6.1. MODELLING ANTICIPATED AND UNANTICIPATED POLICIES**

In all of the above models, the way to model anticipated shocks has been the simulation of that shock prior to its actual implementation. In that way, the anticipation of the future shock, via the forward expectations, is fully modelled by the simulation. For example, Latti and Viren solve QMED four periods prior to the actual shocks. Similarly, Whitley (1994:167-170) models anticipated government expenditure shocks for the LBS, NIESR and LPL models by starting simulations eight periods prior to actual occurrence.



When anticipated policies are modelled, the variable in question will be modified from the time the shock is actually introduced. Given future expectations, current decisions are a function of all expected future values (in line with the Substitution Method). Thus, a future anticipated shock affects current behaviour. The way to incorporate this into the model is to solve the latter prior to the shock so that expectations equal once again model forecasts for the entire simulation period. The model is simulated in the usual fashion to derive strong RATEX. In the case of unanticipated shocks, the model will only be solved from the time the actual shock is introduced.

#### **4.6.2. POLICY MODELLING AND THE CONVENTIONAL METHODOLOGY EMPLOYED IN SOLVING RATEX MODELS**

In models solved with the Substitution Method, the variables subject to exogenous change are not defined as RATEX variables, or more specifically, no policy instrument is identified as a RATEX variable. Anticipation of a shock occurs yet no direct expectations are formed or modelled on that variable. How is this paradox resolved? The answer lies with the Substitution Method. Expectations are indirectly formulated on all variables when the model is solved forward for the defined expectation variables as discussed in Chapter III. Thus, the effect of a shock is channelled indirectly through all other expectation variables. It is therefore the link of the variable in question with all forward looking RATEX variables that initiates a response prior to the actual shock



Should the policy instrument be specified as a RATEX variable, its expectations can be expressed as a function of other exogenous or predetermined variables (see equation (6) and (7) in Section 1.3.2.1.). This could be seen as the expectation function of economic agents with regard to the policy instrument. This is the approach followed in the current study, where the policy instrument is modelled as a policy reaction function. In line with the Substitution Method, this relationship replaces RATEX in the reduced form model. However, because the policy instrument is explicitly modelled, whether a policy is anticipated or not is not an arbitrary question but depends on whether the policy reaction function generates the policy change or not.

Finally, Westaway (1992:88) states that: *'While [the Substitution Method] would seem to require a considerable feat of calculation from the private sector, the RATEX solution [Substitution Method] represents the only solution technique available for directly allowing expected future variables to affect current behaviour'*. The EV method, as interpreted in this study, is argued to be also capable of accommodating anticipated policies but in a structural context. As outlined in Chapter III, uniquely specifying the policy instrument as a RATEX variable as well as utilising the EV method allows the modelling of anticipated as well as unanticipated policies. Indeed, the EV method avoids the Substitution Method's difficulties with regard to uniqueness and stability criteria albeit at the expense of fully consistent expectations. However, as argued, the reliance on weak RATEX need not be interpreted as negative as it is based on assumptions generally regarded as more realistic as outlined in Chapter II.



#### 4.6.3. THE APPROPRIATENESS OF THE EV METHOD

Besides incorporating RATEX in a structural fashion, further characteristics of the EV method are worth noting. The EV method specifies the process by which expectations are formed uniquely for each RATEX variable. This specification is based on the model. However, the underlying rationale for the EV method implies that individuals base their expectations only on single equation estimations. This equation is a simplification of the model yet it should reflect model properties. Thus, when evaluating the expectations (forecasts) of such a single equation, they need to be compared to the model forecasts. This is of course, similar to the Substitution Method. Indeed, the similarity increases when this approach is compared to, for example, Fair and Taylor's approach where a tolerance level exists. In this sense, the EV method can be seen as a very good approximation of model consistent expectations as derived under the Substitution Method. Thus, what is apparent is that the EV method can certainly provide weak RATEX variables and even the strong form should the tolerance level be of adequate size. Indeed, the dimension of the tolerance level is determined by the stationary errors of model forecasts and expectations. To ensure that expectation and forecast differences are confined to a definite limit, the properties of the expectation and forecast time series have to be similar<sup>22</sup>. It is in that regard that one can then proceed to state that the single equation expectations process is a reflection of overall model properties. In conclusion, it needs to be stated that although the EV

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<sup>22</sup>. As already stated, this aspect allows the introduction of cointegration in that should expectations and forecasts be integrated, a necessary requirement for RATEX would be the



method can never derive fully consistent expectations, it can achieve relative consistency within a margin of error, the latter subject to the quality of the single equation specification.

Given that the EV method requires the estimation of a separate expectations process for each expectation variable, each variable upon which expectations are formed has to be defined as such in model specification and all influences are structurally identified. By identifying the expectation process, the EV method allows the modelling of not only anticipated and unanticipated policy responses but also expectation modification due to gradual learning or announced policy responses and in that regard addresses the Lucas critique adequately. How simulation occurs within such a context will be discussed below within the framework of the model of South Africa. The above conclusions are all supported by the discussion in Chapter III which questions a the statement by Hall and Henry (1985:66): *'This procedure [the backward or EV method] fails to explicitly identify the expectation formation procedure, and if there is a policy regime change, for example, then it may not be possible to identify this in the reduced form'*.

#### 4.7. CONCLUSION

The purpose of this Chapter has been to give a broad survey of current national macromodels employing RATEX. In that regard, the LPL, LBS, NIESR and HM

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cointegration of these two time series. Indeed, this is the general way of testing for RATEX if expectations and forecasts are integrated (see, for example Maddala 1992: 599-600 ).



TREASURY models of the UK were discussed as well as MORKMON II of the Netherlands and QMED of Finland. Except for the LBS and NIESR models, all models were solved by the Fair and Taylor iterative technique. This technique can be classified as a practical application of the Substitution Method to non-linear but also linear models. The optimal control technique utilised in the case of the LBS model also falls under this classification just as Hall's approach employed in the NIESR model. All these techniques aim at deriving model consistent expectations in line with the strong RATEX methodology.

The conventional solution methodology for RATEX models differs to the proposed EV method in a number of ways. Firstly, the policy instrument is not a RATEX variable. From a structural perspective, this questions the appropriateness of classifying a policy as anticipated or not as no expectations are modelled or incorporated into the model structure regarding the variable in question. Consequently, the structural impact that such expectations can have on current behaviour is not shown. The solution method well ensures that a future change in a variable can have an anticipated current effect but this is achieved through the solution algorithm deriving model consistent expectations. The expectations as such are not uniquely modelled.

For the linear model considered in this study, the policy instrument is defined as a RATEX variable, thereby accommodating anticipated and announced policies in a structural context. Because the expectation process is not substituted into the model, changes in the expectation process, as would be the case with announced policy changes, can easily be accommodated. The Lucas critique is not

appropriate as expectations are separately defined to the model. However, the expectation process is a reflection of the model and in that way RATEX are derived, if not necessarily in their strong, then certainly in their weak form.



<b>CHAPTER V: MONETARY POLICY AND POLICY MODELLING IN SOUTH AFRICA</b>
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**5.1. INTRODUCTION**

Macroeconomic stabilisation entails the use of fiscal and monetary policy to ensure overall economic balance. Fiscal stabilisation relies predominantly on taxation and government expenditure as policy instruments with the policy target being most often increased employment through higher aggregate demand. This policy gained particular support under the Keynesian argument of active demand management. Monetary policy influences aggregate demand via its influence on investment and other interest rate sensitive demand through altering money supply and interest rates. These policies will induce change in the economy via initial policy impacts but in particular due to multiplier effects.

Fiscal policy instruments have seldom been used successfully in stabilisation policies. The reason lies with the inflexibility with which government decisions are taken. The time dimensions of the budgetary process are not necessarily reconcilable with economic circumstances. Although the budget has a direct impact on aggregate demand, its dimensions are often determined by rigid components such as salaries and interest payments, which are not related to economic events.

In line with most other countries, fiscal stabilisation policies have not been actively implemented in South Africa. A large proportion of current government expenditure consists of salaries, wages, allowances and ancillary payments that cannot easily be lowered without personnel reductions. A further major component consists of social and civil pensions and other statutory commitments, issues that again prevent discretionary adjustments. Although government spending increased substantially during the 1980's, Mohr (1989:287) argues that this did not represent any stabilisation attempt on behalf of government. The reason lies in the composition of government spending with most emphasis placed on consumption spending and public sector pay, the latter factor considered to have counteracted monetary stabilisation (Mohr and Rogers 1987:362-363).

Similarly, taxes have been used primarily as a source of revenue rather than as a policy instrument. The level of taxation has been governed by the level of government spending and the need to keep the deficit before borrowing within limits rather than by broader economic concerns. This effectively ruled out any anti cyclical tax policy for South Africa (Mohr and Rogers 1987:365). Mohr (1989:291) concludes further that given the likelihood of high future government spending, together with the narrow tax base attributable to an unequal distribution of income, there does not appear to be any scope in future for an anti-cyclical tax policy.

The government's current macroeconomic strategy of growth, employment and redistribution (GEAR) places a high premium on fiscal discipline and budget



deficit reduction as a percentage of GDP. The adherence to GEAR denies stimulating policies by government from both, the spending as well as the revenue side of the budget. Also, the introduction of a medium term expenditure framework (MTEF) in 1997, according to which budget planning is carried out for a three year period, reduces further the flexibility of the budget process. These aspects support the conclusion that stabilisation policy will remain the primary responsibility of the South African Reserve Bank (SARB) as has been the case since the 1980's. Accordingly, the focus of the current study falls on monetary policy.

This chapter serves the purpose of covering some of the theoretical aspects surrounding monetary policy as well as providing an introduction to the way in which monetary policy will be modelled. The aim of the first Section is to provide a theoretical background to monetary policy and the issue surrounding the endogeneity or exogeneity of money. This debate can broadly be grouped into Monetarist and Post-Keynesian viewpoints. The relevance for South Africa lies in the fact that the SARB's approach is a combination of the two schools in terms of policy instruments and targets. The discussion will proceed with a broad overview of the operational framework defining monetary policy in South Africa and with a discussion on how monetary policy has been carried out under the presidency of Dr. De Kock and Dr. Stals. The discussion will close with an elaboration on how the primary policy instrument of the SARB, i.e. the Bank rate will be modelled in this study by means of a policy reaction function.

## 5.2. THEORETICAL ASPECTS OF MONETARY POLICY

According to Meijer (1996a: 287), monetary policy describes '*decisions that are made and implemented by the monetary authorities in their various fields of operations to attain or to help to attain, through the influence of these decisions on the volume or composition of domestic expenditure and output or in other ways, certain broad, so-called ultimate objectives with regard to the country's economy*'. The major tools of monetary policy are open market transactions, controls of reserve requirements and interest rate determination. None of these are utilised in isolation but their priority and interaction depends on the Central Bank's perception as to what the most appropriate approach to monetary policy entails. This issue centers on the question of setting policy instruments and targets with regard to magnitudes such as the interest rate or growth in the money supply.

There is considerable disagreement in the economic literature as to how much influence the monetary authorities can exert on price stability and through what mechanism the effects are realised. Two opposing schools of thought developed in that regard namely the Monetarist and the Post-Keynesian school. Both have relevance for the discussion on South Africa's monetary policy.

### 5.2.1. THE MONETARIST SCHOOL

Monetarism represents a revival of the Quantity Theory of Money. The latter is based on the equation of exchange:



$$MV = PY \quad (1)$$

where *M* is the nominal money supply,

*V* the velocity of circulation,

*P* the general price level and

*Y* nominal output.

Equation (1) is an identity derived from the definition of money velocity *V*. Given full employment and velocity determined by institutional factors, both, *V* and *Y* are given values. The Monetarists regard the nominal money supply as an exogenous factor, which allows a causal definition:

$$Mv \rightarrow Py \quad (2)$$

This equation is known as the Quantity Theory, stating that a change in the money supply causes an equal and proportionate change in the general price level (McCarthy 1983:116-117).

The belief that there exists a causal link between money supply and money income (*Py*) has found much empirical support, in particular by the work of Friedman and Schwartz (1963) for the US economy. '*There is unquestionably a close relation between the variability of the stock of money and the variability of income .... The stock of money is much more closely and systematically related to income over business cycles than is investment or autonomous*

*expenditure* ' (as propagated by the Keynesian school). Friedman and Schwarz (1963: 50) claimed to have found support for the Quantity Theory in that *'changes in the stock of money can generally be attributed to specific historical circumstances that are not in turn attributable to contemporary changes in money income and prices. Hence, if the consistent relation between money and income is not pure coincidence, it must reflect an influence running from money to business'*. Further support was given by the Friedman-Meiselman study, a deliberate attempt to compare Keynesian theory with Monetarism (Peterson and Esterson 1992: 709-711).

It follows from the Quantity Theory that monetary policy involves the utilisation of the money supply as a policy instrument with the target variable being price stability. Monetarists argue that in the long run, only prices will increase as output will fluctuate around a natural level<sup>1</sup> *'Our survey ... leads us to conjecture that the longer period changes in money income produced by a changed secular rate of growth of the money stock are reflected mainly in different price behaviour rather than in different rates of growth of output ....* (Friedman and Schwarz 1963: 53)<sup>2</sup>. Thus, inflation and instability is primarily a

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<sup>1</sup>. Given that the demand for money function of monetarists includes real assets, an increase in money supply spills directly over into the goods market. In the short run, this will increase aggregate demand. Given increased prices and the natural state in the long run, all money supply increase will be absorbed by price increases. In the Keynesian demand for money function, additional money balances will lead to a portfolio adjustment that will, subject to liquidity preference, lead to interest rate changes and in that way affects aggregate demand (see Peterson and Estenson (1992), McCarthy (1983:71-92) or Laidler (1985) for a more detailed discussion on the respective money demand functions).

<sup>2</sup>. With regard to South Africa, Naude (1992) found a cointegrating relationship between nominal



monetary phenomenon caused by excess money supply growth. Monetary policy can only have short term real output effects, given a vertical Phillips Curve. Active monetary stabilisation is therefore undesirable, as it will only lead to increased inflation. Friedman proposes a constant money growth rule as the optimal monetary policy as it will prevent monetary policy to become a destabilising factor *'My own prescription is still that the monetary authorities go all the way in avoiding swings by adopting publicly the policy of achieving a steady rate of growth in a specified monetary total. The precise rate of growth, like the precise monetary total, is less important than the adoption of some stated and known rate'* (Friedman 1968:16). Such a growth rule would prevent negative fluctuations and create certainty and thus no inflationary expectations. Indeed, the Federal Reserve Bank applied such a rule for the period October 1979 to mid-1982, resulting in exceptionally high nominal interest rates<sup>3</sup>. However, since that time, the Quantity Theory appears to have lost much theoretical and practical support<sup>4</sup>.

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income and M3.

<sup>3</sup>. Monetarists argue that the Fed never seriously followed a monetarist policy as highlighted by Friedman (1985): *'Insofar as U.S. policy can ever be said to have been monetarist, it was so solely in rhetoric, never in performance. Since the Fed adopted temporarily the rhetoric of monetarism in 1979, monetary growth has been more unstable than in any other postwar period of comparable length. That hardly constitutes a monetarist policy'*.

<sup>4</sup>. Smithin (1990:49) gives an indication of the recent state of monetarism: *'As far as monetarism itself was concerned, by the end of the 1980's the 1979-82 period seemed like the high-watermark of monetarist influence on economic theory and policy. It had become commonplace to refer to the breakdown of Monetarism which had occurred during the decade. Although inflation had been reduced, the centrepiece of monetarist policy recommendations, monetary targeting, had to be abandoned, and the basis for monetarist forecasts of inflation, the historical relationship between the rates of growth of nominal income and the various monetary aggregates, seemed to break down'*.



The money supply is the primary objective of monetary policy and the monetarist's belief that the central bank can and should exert direct control over this target, i.e. the money supply is exogenous to factors such as the interest rate. *'Just as an excessive increase in the quantity of money is the one and only important cause of inflation, so a reduction in the rate of monetary growth is the one and only cure for inflation'* (Friedman as referred to by Stals 1992). How do the authorities achieve this task? The answer lies in the monetary base, which is under the control of the central bank<sup>5</sup>. The monetary base refers to the liabilities of the central bank in terms of currency and commercial bank deposits. Through open market transactions, the central bank forces commercial banks to be "in the bank" implying that cash reserve requirements are equal or in excess of commercial bank deposits. In this way, commercial banks are made to respond to fulfill their cash reserve requirement. The central bank can accommodate the commercial banks through e.g. short-term loans. Alternatively, they can expect the commercial banks to reduce their deposits so that the actual cash reserves are sufficient and in that way exert direct control over money creation. This is in line with the American Cash Reserve System, where open market transaction are aimed at the reduction of total cash reserves i.e. the central bank sets targets for cash reserves and in that way brings about an exogenous target for money supply growth (Black and Dollery 1989:161-

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<sup>5</sup>.  $M = mB$ , where  $M$  refers to the money supply,  $B$  to the base money and  $m$  represents the money supply multiplier. Monetarists maintain that causality is from right to left while Post-Keynesians, as discussed below, claim it to be from left to right. For a detailed discussion on how this equation is derived, see for example, Sijben (1980:15-21).



162). In this case, money supply and demand endogenously determine the interest rates.

Should the Central Bank accommodate commercial banks, the interest rate becomes the policy instrument and money supply an endogenous factor. The Post-Keynesian School supports this view.

### **5.2.2. ENDOGENOUS MONEY AND THE POST-KEYNESIAN SCHOOL**

Post-Keynesians argue that the causality of equation (2) runs the opposite way, thus increased nominal income causes increased money supply via an increase in money demand (Galbraith and Darity 1994:397). Thus, money demand determines money supply<sup>6</sup>. Although Central Banks can exert direct control over the money base, their primary task is one of ensuring financial stability and they will therefore always accommodate commercial banks through the discount window by means of e.g. short-term loans. The only control the central bank has is over the cost of such borrowing activities. Thus, the central bank sets the interest rate and aims at affecting money supply via the interest elasticity of money demand.

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<sup>6</sup>. Moore (1988a:143-170) carried out numerous Granger causality tests on US data to empirically confirm the Post Keynesian view. He (1988a: 163) concludes that *'unidirectional causality runs from bank lending to each of the four monetary aggregates (M1a, M1b, M2 M3). Each monetary aggregate has been shown in turn to cause the monetary base unidirectionally. These results provide empirical support for the Horizontalist view of the endogeneity of the monetary aggregates. Changes in the money stock are attributable primarily to changes in the demand for bank credit'*.



Post-Keynesians argue that the primary cause of inflation is not excess money growth but cost-push inflationary factors such as exogenous wage increases, which, in term, increase the money supply<sup>7</sup>. Thus, the causality is reversed. *'Monetarists argue that money stock changes are exogenously determined by the central bank, and that excess money growth causes money wages to raise .... Post-Keynesians argue that money wage growth is more nearly exogenous, and the Central Bank is viewed as forced to accommodate to money wage increases to prevent unemployment rates from rising '* (Moore 1988b: 138-139). Should inflation be primarily attributable to exogenous cost-push factors, the effectiveness of the Central Bank to exert some control over price increases is restricted. As discussed below, much support can be given that the SARB faces such an inflation process. Post-Keynesians argue that monetary policy is less effective in curbing inflation and propose rather the introduction of, for example, an income policy.

The effectiveness of monetary policy in curbing inflation depends on the interest elasticity of credit demand. Credit demand influences expenditure and

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<sup>7</sup>. Post Keynesians regard prices to be primarily determined as a mark up over cost. Inflation, as well as an increase in the money supply are then both the result of cost push factors. *'Under cost inflation, firms will continue to increase their bank borrowing to finance their increase working capital requirements. The credit money supply will increase par pasu with the wage bill, prices and nominal income'* (Moore 1988a: 350). On a more fundamental level, they maintain that inflation is a reflection of the struggle over the distribution of income, a view that is in line with the conflict approach (Davidson 1991: 88-92). Thus, whereas the monetarists maintain that inflation is always a monetary phenomenon, Davidson (1991: 92) maintains that *'Inflation is always and everywhere a symptom of the struggle over the distribution of income'*.



in that way can counteract demand push factors. Higher interest rates can also affect the willingness of enterprises to increase their cash flow to accommodate wage increases<sup>8</sup> and can in general affect the cost structure of firms and therefore their profitability, a factor that could again counteract wage increases. All of these links are, however, indirect mechanisms in combating inflation, an aspect again discussed in a South African perspective below.

In conclusion, it can be said that the Post-Keynesian school maintains that interest rates are exogenous policy instruments and money supply not only an endogenous factor but a target of little relevance in combating inflation as the latter's cause is not excess money.

### **5.2.3. EXPECTATIONS AND MONETARY POLICY**

According to Taylor (1982:47) two views prevail with regard to the impact expectations have on monetary policy. On the one hand, there is the New Classical view, proposing that expectations overwhelm the influence of monetary policy as individuals form RATEX and will anticipate policies. However, as indicated in Chapter II, only under additional assumptions will this lead to policy ineffectiveness. The other view is that expectations matter little, as they are exogenous and backward looking. This is based on the

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<sup>8</sup>. Prices are fixed in the short term (e.g. they are already quoted) so that the cash flow can come under pressure from increasing costs.

unsatisfactory preposition that individuals form adaptive expectations<sup>9</sup>. The continuous theme so far has been to emphasise the importance of expectations and more so, their proper modelling and it should be trivial to elaborate on the unsatisfactory nature of the second viewpoint.

One aspect to note in RATEX modelling of monetary policy is that conventional Granger causality tests are likely to be misleading. These tests are based on the preposition that a future event cannot cause current changes. However, future expectations, allowing anticipated monetary policies, will cause future events influencing current decision-making. This test, often employed in equation specification and more specific, in distinguishing exogenous from endogenous variables, has to be employed with great caution in RATEX modelling. Model and variable specification will have to rely more heavily on a priori economic theory.

Sijben (1980:71) argues that: *'Systematic monetary policy actions consist of simple rules or reaction functions which relate economic policy variables to lagged values of other economic variables. These policy reaction functions can be estimated and then be incorporated into the prediction of the expected rate of inflation...'* This, in essence, is the strategy followed in this study. As spelled out below, the SARB's policy has been consistent and allows the modelling of a policy reaction function, the latter inducing the formation of

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<sup>9</sup>. Taylor (1982:47-76) proposes an approach that reconciles the two extreme views by incorporating forward expectations into a model with sticky wages.



RATEX by economic agents. The feasibility of such a reaction function enforces the need to model monetary policy in South Africa within a RATEX framework.

#### **5.2.4. EXPECTATIONS AND POLICY LAGS**

When evaluating a policy, reference is usually made to policy lags. These include inside lags (the time between the signal and actual decisions taken by authorities) and outside lags (the time between the change in the policy instrument and its effect on the target). Given that channels of monetary policy depend on numerous intermediary links, the outside lag is generally regarded as being longer than that of fiscal policy, in which case government expenditure directly affects aggregate demand (Mohr and Rogers (1988:267)).

In the modelling of a policy, the outside lags reveal themselves through the simulation path of the target variable and the model as a whole. Under RATEX, these outside policy lags can be expected to be much shorter. In the case of an anticipated policy the recognition lag of the authorities equals the private recognition lag of a policy response. From that point onwards, economic agents' behaviour changes already. Indeed, the SARB's recognition and decision lags are concurrent with the individual's anticipation lag while the implementation lag will be altered due to RATEX.

In the case of unanticipated policy modelling, the economic agents do not anticipate the SARB's internal lags so that a behavioural adjustment will only

occur with the implementation lag.

As is below suggested, the SARB's direct influence over its ultimate target is limited. Similarly, the influence on their intermediary target depends on, among other things, the interest elasticity of credit demand and aggregate demand. The effectiveness of monetary policy depends therefore very much on the strength of these links in the causal chain whereas the latter appears to be fairly long. This suggests that the lag between a change in the policy instrument and a favourable response in the target could be longer if not anticipated.

#### **5.2.5. POLICY SHIFT SINCE THE EARLY 1980'S**

The presence of policy lags introduces the much-debated controversy of active versus passive policies and the question of whether monetary policy can be used to fine tune the economy. Whereas Keynesian proponents favour active stabilisation albeit preferably fiscal in nature, the Monetarists see more harm than good in active stabilisation, particularly monetary stabilisation. Keynesians see the problem with monetary policy in the numerous links that can break (e.g. the liquidity trap), while Monetarists go further and argue that any expansionary monetary policy, unless synonymous with a constant money growth rule, is in itself, a destabilising factor as it will likely accelerate the inflation process (Friedman 1968:1).

Since the early 1980's, there has been a shift in the views regarding what monetary policy is or should be and what it should try to accomplish (Fourie,



Falkena and Kok 1996:208). The emphasis shifted away from the Keynesian demand management approach to what has become known as Reaganomics in US and Thatcherism in the UK. Under this new approach, monetary policy was no longer perceived as a major instrument in the manipulation of aggregate demand but rather of central importance in the creation of a stable financial situation (Gidlow 1995:4). This change in priorities can partly be ascribed to the revival of the monetarist school.

Within the context of this study, the controversy of active monetary stabilisation finds little relevance, as the SARB's focus is not so much on stabilising the business cycle for employment purposes but rather to maintain financial stability. Its view is therefore supportive to the monetarist perception that monetary policy should provide a stable background for the economy and avoid money itself to become a destabilising force.

A further new international development has been the increased focus on targeting inflation directly rather than monetary aggregates. Although the Governor of the Reserve Bank referred to the possibility of inflation targets for South Africa (Stals:1996b, 1999), no concrete policy proposals have yet been made. Also, this development is outside the estimation period of the model<sup>10</sup>.

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<sup>10</sup>. For a discussion on the appropriateness and feasibility of inflation targeting for South Africa, see Casteleijn (1999) or Jonsson (1999).

### **5.3. SOUTH AFRICA'S MONETARY POLICY**

The aim of this section is to give an overview on South Africa's monetary policy. The section can broadly be divided into two parts. The first Section briefly discusses the policy recommendations of the De Kock commission and monetary policy under the governance of Dr. De Kock and Stals. The remaining Sections focus on the modelling of monetary policy and in particular on the specification of a policy reaction function for the SARB's Bank rate, transmission mechanisms as well as previous studies.

#### **5.3.1. RECOMMENDATIONS OF THE DE KOCK COMMISSION**

##### **5.3.1.1. Primary and Intermediary Objectives of Monetary Policy**

The De Kock Commission defined monetary policy rather broadly as '*all deliberate actions by the monetary authorities to influence the money supply aggregates, the availability of credit, interest rates and exchange rates with a view of affecting monetary demand, income, output, prices and the balance of payments*' (Gidlow 1995:4).

The domestic and foreign protection of the value of the rand is the ultimate long-term aim of the SARB. Given numerous factors that affect price stability that are not directly under the control of the Bank, the De Kock commission identified the growth in the money supply as an intermediate policy target with interest rates



being the primary policy instrument<sup>11</sup>. *The Commission believes that the excessive and highly unstable growth of the monetary aggregates has been a prime element in both a causal (or initiating) and permissive (or accommodative) sense in accounting for the inflationary experience of the past twenty years or more*' (De Kock 1985:15.26). This statement shows that the Commission appears to have taken a monetarist view on the inflation process. *The Commission finds that the excessive and unstable growth of monetary aggregates...has been a major cause of inflation*' (Mohr 1985:24). Mohr (1985:25-26) correctly maintains that correlation gives no statement regarding causation and that the Commission's conclusion lacks sound empirical verification. However, the Commission did point out that money supply is a major cause but not the only cause of inflation (Mohr 1986:25). Nevertheless, they identified money supply as the primary intermediary policy goal.

#### **5.3.1.2. Market Orientated Instruments**

The main recommendation of the De Kock Commission is a monetary policy framework that is essentially market orientated. The Commission made a strong plea for a move away from direct policy measures to indirect or market orientated once. It persistently stressed the need for well functioning and freely operating financial markets (Meijer 1996b: 242). The De Kock Commission (1985:17.2) came to the conclusion that in the sophisticated financial system

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<sup>11</sup>. Another policy instrument that has been used by the Reserve Bank is the variation of the cash reserve requirement.

that had developed in South Africa, a market related monetary strategy would serve the national interest best.

The primary reason the Commission (1985:17.3-17.4) gave for this conclusion was that the promotion of well functioning financial markets would support the economic goal of efficient resource allocation. Under direct measures, a great amount disintermediation occurred and interest rates did not reflect a market clearing level. The ability of markets to co-ordinate was severely undermined. By taking this view, the Commission placed South Africa's monetary policy in line with a global tendency towards financial market liberalisation.

Direct policy measures involve the central bank telling banks what to do or what to refrain from by means of official rules and regulations. Credit or interest rate ceilings are typical examples. Indirect policy measures are more market orientated as they operate through the market to manipulate e.g. interest rates. Banks respond to these measures voluntarily in their strive to profit maximization (Fourie et al. 1996:226-227). The primary market orientated measures or policy instrument recommended by the De Kock commission (1985:17.46) are open market transactions, discount policy and public debt management.

#### **5.3.1.3. The Classical Cash Reserve Requirement and Open Market Transactions**

The Commission regarded open market transactions as an important policy



instrument. According to Meijer (1984:474), open market operations '*consist of decisions...regarding the timing, volume and nature of the sales or purchases of domestic financial assets, which are made at the initiative and discretion of the SARB from a potentially broad range of domestic financial institutions and other market parties*'. Open market transactions involve the selling or purchasing of domestic financial assets to influence the cash or liquidity base of the banking system, interest rates and the availability of credit (Gidlow 1995: 52).

The SARB has mixed the selling of financial assets from their own portfolio with debt paper supplied by the Treasury on tap. Thus, the SARB's open market operations are '*a blend of public debt management and conventional central bank open market operations that serve the purpose of financing Exchequer's deficit as well as the purpose of monetary control*' (Meijer 1996a: 309). The need for a close coordination between government borrowing activities and open market operations arises from their similar immediate impact on banks cash reserve positions (Meijer 1996a:303)<sup>12</sup>.

The De Kock Commission recommended the classical reserve system (Meijer 1996b:242). This approach emphasises the 'lender in the last instance' function of central banks and is aimed at controlling the price at which accommodation is given rather than the quantity of accommodation and thus the money supply. Accordingly, open market operations are not directly aimed at reducing the

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<sup>12</sup> The SARB also uses the Treasury's Exchequer and Tax and Loan accounts to influence liquidity.

money supply or to directly influence the cost of credit. Instead, they serve the purpose of influencing the cash reserve balances of banking institutions with the SARB. The open market operations force commercial banks to utilise the Central Bank's lending facilities and thereby ensure that banks are 'in the bank' (De Kock 1985:17.60). This, in terms, allows the SARB to enforce their interest rate policy. Thus, open market operations under the classical system serve the important purpose of making the SARB's discount policy effective.

### **5.3.2. THE BANK RATE AS THE PRIMARY POLICY INSTRUMENT OF MONETARY POLICY**

By utilising the classical cash reserve system, the De Kock commission effectively suggests a Post Keynesian approach to monetary policy even though it supports a monetaristic view on the inflation process. *'By opting for what it calls the classical system of monetary control the Commission is embracing the Wicksell-Post Keynesian analysis of the money supply process.... Cash reserves are a derived quantity-the end result of the Bank's monetary policy as reflected by the Bank rate'* (Rogers 1986:74).

The interest rate is the primary instrument for monetary policy and consequently, it has to be at a level where it can be effective in transpiring monetary policy goals at all times. In that regard, the De Kock Commission emphasised the importance of market related interest rates. *'If effective control is to be exercised over the monetary aggregates and total monetary demand, interest rates must be free to reflect accurately the varying degrees of tightness*



*in financial markets resulting from the combined operation of natural economic forces and monetary policy actions'* (De Kock 1985:17.12). The De Kock Commission recommended the utilisation of the Bank rate as the SARB's basic rediscount rate. At that time, the Bank rate referred to the rediscount rate the SARB offered on treasury bills.

The Bank rate dictates the money market interest rates and is the single most important price in the financial system as it constitutes a ceiling to the treasury bill rate and therefore to other money market rates (Gidlow 1995:75). The dominance of the Bank rate over other money market rates is in essence the effect of arbitrage transactions. For example, should the TB or BA rate be substantially lower than the Bank rate, banks would want to utilise these assets in complying with their cash reserve requirement. Instead of rediscounting these assets with the SARB at the Bank rate, they would sell BA's or TB's into the market to generate the liquidity to fulfill their obligations<sup>13</sup>. This would lead to an increase in these interest rates, as the increased supply would see the price of these securities decline. Under normal circumstances, these interest rates would never exceed the Bank rate, as this would lead banks to borrow or rediscount their bills at the discount window and buy bills in the market. In this case, the SARB would be a cheap source of finance<sup>14</sup> (Kock and Meijer

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<sup>13</sup>. Ultimately, it is only the SARB that can create or destroy liquidity. The banking sector as a whole cannot reduce or increase its indebtedness to the bank. However, transactions by individual banks will influence their liquidity positions.

<sup>14</sup>. It is well possible that liquidity conditions suddenly tighten to such an extent that the money market rate exceeds the Bank rate. In this case, the Bank rate would have to respond to money market rates. This was the case in 1996, where substantial capital outflows rose money market



1987:165-166).

Before the implementation of the De Kock commission's recommendations, the prime rate was mechanically fixed to the Bank rate, allowing commercial banks to vary their prime rate only within a prescribed margin from the Bank rate (Fourie et al. 1996:293-294). The De Kock Commission opposed any direct or fixed link between the Bank rate and prime overdraft rates of banks, as this would be in conflict with the market orientated approach of the Commission (De Kock 1985:20.62).

### **5.3.3. MONETARY POLICY UNDER DR GERHARD DE KOCK (1981-1989)**

From the late 70's increased recognition emerged among countries of the need for realistic interest rates freely determined in operational financial markets as an indispensable element of an anti inflationary monetary policy (Meijer 1996b: 241). The De Kock Commission's recommendations ensured that South Africa followed this trend. Although the final report was only submitted in 1985, monetary policy has been in line with the recommendations of the De Kock Commission since the early 1980's.

According to Gidlow (1995:4), *'monetary policy in South Africa during the De Kock era could best be described as a market orientated blend of conservative*

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rates and necessitated a Bank rate increase. Another reason why market rates on rediscountable instrument may be substantially higher or lower is that market expectations of what the SARB's rediscount rate will be could be different to the prevailing rate (Kock and Meijer 1987:166).



*Keynesian demand management and monetarism*'. The SARB has been following a Post-Keynesian approach in terms of policy but, since 1986, it has also set money supply targets. These targets were specified by means of 5 per cent money growth bands. However, the De Kock Commission explicitly stated that these targets should not serve as the sole focus of monetary policy and a possible money growth rule but rather as a guideline on the stance of monetary policy<sup>15</sup>.

During the 1980's monetary policy was conducted in a crisis atmosphere as a result of persistent financial instability reflected in high inflation, sharp interest and exchange rate fluctuations (Gidlow 1995:12). The South African economy was hit by a number of political and economic shocks. The gold price dropped from an all time high of US\$ 850 per ounce in January 1980 to US\$296 per ounce in June 1982 and there were serious droughts between 1983 and 1985. In addition, the political environment forced South Africa to become a capital exporter since 1985 (Coelho 1992:31). All these external shocks brought about great variation in economic growth, inflation, money supply growth and the balance of payments. This caused at times sizeable changes in the Bank rate, resulting in excessively high interest rate levels and volatility.

A reduction in the money supply only leads to lower prices if the monetary perspective prevails where the money supply is believed to be exogenously determined by the Central Bank and excess money raises prices. From a Post-

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<sup>15</sup>. Gidlow (1995:34) mentions in that regard that the targets were not set to reflect the effective increase in the money supply but rather to represent an inflation reducing target for M3.



Keynesian perspective, money (credit) demand is endogenously determined by factors such as wages and will consequently set the money supply. The SARB's policy approach is Post-Keynesian in nature in that it sets the interest rate to have an impact upon money demand and thus supply. However, trying to lower money demand through interest rates will not directly have an impact on prices as the latter are determined by factors such as expected inflation, wage adjustments and demand pressure. Thus, although the SARB responds to changes in the money supply to restrict price increases, this restriction is achieved through the impact interest rate changes have on, among other things, aggregate demand. The latter will partly affect the demand for credit money and hence the money supply.

#### **5.3.4. MONETARY POLICY UNDER DR CHRIS STALS**

In 1989, Dr. Stals took over as governor of the SARB an event accompanied by an official change in policy formulation<sup>16</sup>. The SARB still functions according to the De Kock guidelines. However, while the De Kock Commission isolated money supply as the primary cause of inflation, the current view is a pragmatic combination of Monetarist theory and Post-Keynesian practice: *'Other factors such as excessive salary and wage rises, excessive government expenditure*

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<sup>16</sup>. In 1989, a Law (Act 90 of 1989) was passed that defines (Article 3) the responsibilities of the Reserve Bank. Consequently, the Bank formulated a mission statement, namely the protection of the domestic and foreign value of the rand. Although since then official, the Reserve Bank has followed this mission implicitly ever since the De Kock commission. The only difference lies in greater autonomy from the state. In the 1980's political pressure still influenced interest rate policy, even though it was restricted to times of elections.



*and, at times, import inflation, all contribute to the ever-rising prices in this country. And this is, of course true. The question does arise, however, whether these other non-monetary causes can ever lead to sustainable price rises if there should be no addition to the money supply to support the higher volume of nominal turnover .... The power of transmission of these other inflationary factors lies in the support of a simultaneous expansion in the money supply'* (Stals 1992). Thus, Stals also sees the root cause of inflation in increased money supply. Should the SARB enforce its money supply targets by denying credit to commercial banks, cost push factors could not persist. *'It is true that central banks ..., often are too accommodative and therefore facilitate the escalation of inflation caused by non-monetary factors '* (Stals 1992).

In the light of the previous statement, why does the SARB not strictly adhere to a monetaristic growth rule? The answer lies with the political feasibility as well as the SARB's responsibility towards the financial sector. With regard to political pressure, money creation is an easy way out of the conflict of interest groups for an increased share of national income, increased unemployment and uncompetitiveness: *' We all seek for an alternative to the obvious, and see in the creation of more money an illusionary solution to the dilemma of rising wages'* (Stals 1992). Stals (1992) places the responsibility of lower inflation upon all economic participants. *'The private sector may be crowded out ...by the rationing of bank credit and higher interest rates. Such a restrictive monetary policy could be more painful ... than a correct fiscal policy in the first instance. Monetary policy may be enough to curb inflation but is advisable to have a more comprehensive and coordinated overall strategy to fight inflation....*

*Monetary policy can perhaps do it alone, but then only at a cost that will in the long term not be palatable in a democratic society*'. The SARB prefers therefore to provide unconditional accommodation when required at a price it hopes will dampen money supply growth.

The SARB's view is one where the rate of inflation is not under the direct influence of the Bank but the latter can make a major contribution to the achievement of lower inflation. In that regard, the Bank set itself certain intermediary objectives as stipulated by Stals (1992):

1. Money supply must be low enough not to stimulate inflation.
2. Bank credit to government and private sector must be constrained.
3. Real positive interest rates have to prevail to successfully influence money supply via money demand.
4. Adequate gold and foreign reserves have to prevail.

These objectives are in line with the De Kock commission and monetary policy in the 1980's.

The utilisation and interpretation of money supply guidelines was continued under Stals. The purpose of these targets *'is to communicate to the public and the Government what range of change in M3 is regarded by the Reserve Bank*



*as appropriate* ' (Stals 1989). In 1992, the spread between the money supply targets was reduced to 3 percentage points. As was the case during the 1980's, the SARB has not been very successful in meeting its money supply criteria (Moll 1999:40-42). However, just like the 1980's, the early 1990's have been a time of economic and political instability and change, which made monetary policy so much more difficult.

Since 1 May 1993, a new system of accommodation came into effect according to which the SARB only grants overnight loans to banks in their strive to meet their cash requirements. Since then, the Bank rate has referred to this accommodation rate for these loans against collateral of treasury bills as well as other government stock with a maturity of less than 92 days.

A further change has been the introduction of a Tax and Loan Accounts system in May 1993 (Schoombee 1996:88-90). Up to then, the government was exclusively banking with the SARB which caused large fluctuations in money market liquidity as any transfer from the private sector to the government implied a reduction in the money supply while any government spending led to an immediate increase. Under the new system, the government holds accounts with private banks in addition to the Exchequer Account with the SARB. This has not only reduced fluctuations in liquidity, it has given the SARB an additional instrument of liquidity management as it can shift funds within government accounts to affect the money market shortage.

On 8 March 1998, a new system of bank accommodation was introduced. The



Bank rate was replaced with the repo rate, which is the interest rate on repurchase transactions charged by the SARB. This new system is aimed at increasing interest rate flexibility by inducing market participants to compete for a given amount of accommodation. On 1 April 1998, the government has also appointed twelve primary dealers, thereby removing the SARB's responsibility of a primary market maker for government debt.

### **5.3.5. SOME THOUGHTS ON THE NATURE OF MONETARY POLICY IN SOUTH AFRICA**

Kane (1982:182) states that '*The presumed linkage between movements in targets and current and future movements in goal variables lets targets serve as proxy variables*'. Although a close movement of the money supply and price changes is observable, taking money supply as a target for inflation presumes the monetarist model as causality is assumed between targets and goals. Furthermore, it is not enough to specify policy instruments, targets and goals. Two further steps are essential namely the SARB must spell out differences in the projected linkage between its targets and goals over time spans of different lengths, and it must explain the feedback process that lead it to alter the current settings and even the identities of the intermediate targets it uses (Kane 1982:182). Thus, good monetary policy requires the announcement of a feedback or policy reaction function by the monetary authorities. To a certain extent, the SARB has succeeded with this task. Although it is far from any formal specification of a reaction function, it persistently emphasises the signals that cause it to respond.



Kane (1982:185) maintains that targets are most helpful if they meet four conditions. These are the following:

- Replace hard to sight targets by easier ones
- Reduce dimensionality of the sighting problem
- Remain in a fixed relation to ultimate goal
- They are an effective means to influence the target

The money supply targets of the SARB fulfill the first three conditions. The money supply is an unambiguous and easily identifiable and quantifiable target. It also lacks multiple interpretations and multiple means of measurement. Inflation is affected by a vast number of variables, some of which are not under the influence of the SARB. The money supply, on the other hand, is a more definable target that can be influenced. That there is a relationship between the money supply and inflation cannot be questioned, irrespective of the doctrinal school. As, however, indicated in the theoretical discussion, the effectiveness of the SARB's target can be questioned on Post-Keynesian reasoning.

If the money supply is credit driven, not only has the SARB no direct control over its target variable but focusing solely on the latter could lead to the neglecting of the ultimate target as inflation is a multidimensional problem. In that regard it needs to be asked whether the money supply target is not simply an indicator for the SARB (and private individuals) of the inflation process and not an isolated target. In such a context, interest rate changes would be directly

aimed at inflation control with the side effect being lower money supply growth. Indeed, given the inflation process and money demand processes as further discussed below, this scenario is reconcilable with and projected by the SARB (as revealed by Stals in the above statements on the nature of inflation, M3 targets and the SARB's approach in that regard). Thus, the money supply should not be seen as the SARB's target variable but rather as its indicator of the inflationary process and consequently monetary policy. However, the velocity of circulation has been fairly unstable in South Africa so that the time lag between money supply and inflation is difficult to quantify. It is from this perceptive that increased focus falls on direct inflation targeting as monetary aggregates have proven to be poor leading indicators of inflation<sup>17</sup>.

### **5.3.6. MODELLING SOUTH AFRICA'S MONETARY POLICY**

#### **5.3.6.1. Policy Reaction Function and RATEX**

A reaction function attempts to answer what macroeconomic variables (independent variables) does a policy authority react to and with what operating instrument (dependent variable). A reaction function is a reduced form equation and the coefficients do not directly reveal the weight a policy authority places on the explanatory variables. Instead they represent a combination of structural

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<sup>17</sup>. The instability of the velocity of circulation does not necessarily make money supply guidelines/targets redundant and it does also not necessitate the introduction of inflation targeting. The Bundesbank, for example, has been on average successful in meeting its money supply guidelines in spite of an unstable velocity. The challenge is to forecast the change in velocity in conjunction with other economic variables (Bundesbank: 1995:78-88).



and utility parameters (Havrilesky, Sapp and Schweitzer 1976:723). If the structure of the economy is unchanged, changes in the coefficients represent changes in the utility or preference parameters and thus a change in focus or emphasis by the policy authorities.

Due to its consistency in terms of policy announcements and implementations, the SARB can be regarded as following a policy reaction function, with interest rates as policy instrument and numerous inflation indicators that the SARB regards as important as explanatory variables. The most relevant indicators used by the Bank appear to be money supply growth and/or growth in bank credit (Stals 1996a). According to Meijer (1996b: 246), further possible factors include the current and or capital account of the balance of payments, the exchange rate or foreign reserves as well as developments in the money and capital markets. These aspects are indirectly confirmed by Stals (1996a)<sup>18</sup>.

Given the persistent policy of the SARB, rational individuals are capable of forming RATEX concerning the Bank rate. In its mission statement, general economic reports as well as actual policy implementation, the SARB describes its policy reaction function to economic agents so that the latter can form expectations of the interest rate based on that function. The fact that RATEX can be formed on a policy instrument such as the interest rate introduces the

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<sup>18</sup>. As far back as in the third quarter Quarterly Bulletin of 1989, Stals makes the following statement: *'In deciding on the monetary policy stance, the Reserve Bank will pay attention not only to the behaviour of M3, but also to ... changes in other monetary and credit aggregates, the exchange rate ... prices and other economic indicators...'*. He also identified M3 growth, inflation, wage increases and balance of payments constraint as primary determinants for interest



problem of the Lucas critique. This implies that policy modelling has to explicitly accommodate such expectations formation in policy simulations.

Concerning exchange rate policy, the SARB intervenes in the market with a view to stabilise the value of the rand over the short term. The policy instrument used in that regard is foreign exchange reserves. Rational individual will again take these aspects into account, although foreign reserves would certainly not be the only variable to consider in their expectations, given the full utilisation of all available information and the numerous factors affecting the exchange rate. Indeed, factors outside the control of the monetary authorities (e.g. international changes in interest rates or prices) are likely to dominate exchange rate movements.

#### **5.3.6.2. The Specification of a Policy Reaction Function**

The SARB states the ultimate goal of monetary policy as price stability and specifies monetary targets as intermediary guidelines. The inclusion of money or credit growth in excess of inflation is therefore essential for a proper specification of the SARB's reaction function. A further responsibility is the balance of payments, which caused severed interest rate responses particularly during the 1980's. A measure of the current and or capital account needs therefore inclusion as a dependent variable. Pretorius (1994) tried an extensive number of independent variables in a specification explaining changes in the Bank rate. He (1994:16-18) states that the current account, the percentage change in the gold

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rate changes.



price, the percentage change in M3 as well as the percentage change in real GDP served best for the period 1979 to 1989. A dummy variable is also included for the 3rd and 4th quarter of 1985. Since the early 1990's the best specification according to Pretorius (1994:19-29) includes the inflation rate as a variable but excludes the gold price<sup>19</sup>.

The reason why the current account is believed to be a relevant variable is given by the SARB's concern regarding the import-foreign reserve ratio. During the 1980's the SARB had to increase the Bank rate and thereby reduce aggregate demand on numerous occasions because of the deteriorating current account. However, this policy reaction was only necessary because the capital account was not favourable. The current account only poses a problem if the capital account does not compensate for a possible deficit. Consequently, looking only at the

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<sup>19</sup>. For the Federal Reserve, Fuhrer and Moore (1995) model monetary policy as a reaction function that relates changes in the 3 month TB rate to lagged changes in the TB rate, lagged levels of the inflation rate and the contemporaneous level of output. The interest rate is lagged one and two quarters while inflation is lagged by one, two and three quarters (Fuhrer and Moore 1995:225-226). In an earlier study, Havrilesky (1976) used total reserves adjusted for the legal reserve requirement (excess reserves) as the dependent variable in a reaction function of the Fed. Such a reaction function reflects the view that the money supply rather than interest rates is the policy instrument and is in line with the monetarist view. Khoury (1990) evaluated 42 Federal Reserve reaction functions. Independent variables included were growth, unemployment, inflation, the balance of payments, the exchange rate, deficit, debt and interest rates (Khoury 1990:29). Dependent variables included interest rates as well as monetary aggregates. After carrying out specification tests, he (1990:38) concluded that very few variables were robust in the reaction functions with unemployment, growth and the exchange rate being the most prominent.

In the UK, the Taylor rule has gained increased popularity as a reaction function. Accordingly, the official interest rate is as a function of the equilibrium real interest rate, the current inflation rate, current inflation less the inflation target and the excess of actual output over potential. Alternatively, the equation can be specified according to a money supply target (Bank of England



current account is inadequate for predicting monetary policy reactions. Given that the exchange rate is a reflection of primarily capital but nevertheless also of current account movements, the exchange rate captures the SARB's concern regarding the balance of payments as a whole and is therefore proposed to be a more suitable measure. The current study uses the real effective exchange rate. It not only captures substantial balance of payments movements but also allows the reaction function to fully reflect the SARB's mission statement, which is the protection of the internal and external value of the rand.

In the reaction function of this study, the internal value of the rand is represented by real money or credit growth and inflation while the external value of the rand is given or best approximated by the real effective exchange rate. Any sharp movements of the real exchange rate will further have domestic inflationary implications that the SARB cannot ignore. The average real effective exchange rate depreciated sharply by 8,13 per cent in 1996. In response, the Bank rate was increased by one percentage point at the end of April and again in November. Partly as a result of this depreciation, the average inflation increased from 7,4 per cent in 1996 to 8,6 per cent in 1997. In spite of weak domestic demand and substantial capital inflow in the first half of 1997 that caused net foreign reserves to increase from R11,7 billion in January to R20,6 billion in August, the SARB did not lower the Bank rate before 21 October 1997.

The sign of the coefficient concerning the exchange rate should be positive. If the real effective exchange rate depreciates substantially (e.g. as a result of a net



deficit on current and/or capital account), the SARB will exert upward pressure on the Bank rate, an aspect that has become particularly evident during the 1980's and 1996. The motivation is given by possible inflationary pressure and thus expectations of further depreciation or by the need for foreign reserves. If the real exchange rate appreciates and therefore leads to increased foreign reserves, South Africa's competitiveness is negatively influenced but on the other hand, foreign reserves accumulate satisfactory and inflation pressures are reduced. Both of these aspects suggest a reduction in the Bank rate.

#### **5.3.6.3. Channels of Monetary Policy**

Should interest rates be a significant<sup>20</sup> regressor in the money (credit) demand equations, the SARB can exert direct control over the money supply. However, of vital importance in that regard is the stability of the demand function. As Rogers (1985:244) points out: *'By raising or lowering interest rates the Central Bank can, in principle, loosen or tighten the monetary target so long as the demand for money and credit is stable.... Should it not be stable, 'there is no guarantee that nominal interest rates will ever be high enough to hit a particular target'*. Thus, high nominal interest rates might not bring about restrained monetary growth. This leads Post-Keynesians to conclude that monetary targeting is not a feasible policy recommendation, a statement

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<sup>20</sup>. Significance not only refers to statistical probability but also to the magnitude of that coefficient and therefore the interest rate elasticity of money demand (assuming log transformations).

supported by the Reserve Bank, given the interpretation of their money guidelines. In the case where significance of the interest rate regressor is not found or demand instability prevails, monetary policy has to work through the impact high interest rates have on economic activity. In this case, the Central Bank controls monetary growth indirectly, via aggregate demand and therefore income, a regressor certainly significant in a money demand function.

By raising the short-term interest rate, the SARB affects aggregate demand primarily through a reduction of interest sensitive private consumption expenditure and investment. Should cost-push inflationary factors such as wage increases or exchange rate depreciations occur, the SARB can only raise interest rates to counteract inflationary pressure through a further reduction in aggregate demand<sup>21</sup>. Should, however, wages be partly determined by company profits (profits are affected by interest rates as a component of the cost structure of the firm) or future price expectations, interest rate changes could have a second link to price changes.

All transmission mechanisms, namely the direct influence that interest rates have on the money supply and aggregate demand as well as the latter's influence on wages, can be identified in the econometric model specified in detail in the next Chapter. In addition, the explicit modelling of expectations provides further mechanisms.

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<sup>21</sup>. Ideally, the imposed recession should moderate wage claims and therefore dampen inflation. However, wage claims are often an exogenous factor that is not business cycle related.



#### **5.3.6.4. Previous Econometric Studies on Interest rates, the Demand for Money and Inflation in South Africa**

A study by Nel (1994) provides strong support for the ability of the SARB to influence market interest rates<sup>22</sup>. This is not surprising, given the profit motive of commercial banks and their narrow profit margins in the light of intense competition. Nel also found a significant negative correlation between the yield curve and the Bank rate.

As pointed out, to determine the effectiveness of interest rate changes, several links can be evaluated such as the interest elasticity of money demand and aggregate demand or the demand elasticity of inflation. Numerous studies have been carried out with respect to the demand for money in South Africa. Stadler (1980) and Contogiannis and Shahi (1982) gave early studies of money demand functions. Stadler utilised the conventional Keynesian approach where money demand is positively correlated with income due to the transaction motive and negative correlated with interest rates due to opportunity costs (or the precautionary motive). In all of his regressions, interest rates have the incorrect sign and have been insignificant in most cases. Contogiannis and Shahi obtained similar results. They (1982:31-32) explained these results by pointing to the fact that interest rates in South Africa have not always reflected true money market conditions. A much more extensive study has been undertaken

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<sup>21</sup>. Using monthly data, he found a strong correlation between changes in the Bank rate and changes in other market interest rates, particularly since 1988.

by Courakis (1984). Although finding that interest rates are significant determinants, he maintains that expected inflation has a far greater impact on determining money demand. Finally, Naude (1992) who followed an Error-Correction approach has provided a more recent study. He too, found a significant relationship between interest rates and money demand.

All studies tend to support the view that the money demand equation is fairly unstable. Naude (1992:60) maintains that a broad definition of money (M3), which includes close substitutes, should be more stable and hence used as monetary targets (all studies used M1 or M2). Furthermore, all studies utilised adaptive expectations in modelling inflation or income expectations. They were all single equation specifications.

Moore and Smit (1986) provide evidence that South Africa's broad monetary aggregates have been credit driven. Aggregate demand for money is primarily determined by those factors that determine the demand for credit money by the private sector. However, in the same study Moore and Smit (1986) support the view that changes in credit demand are primarily a function of wage changes and not interest rate changes. Growth in credit could therefore best be modelled as a function of wages and other cost-push factors. This would imply that the SARB has little direct control over credit extension and thus money demand. This conclusion supports the Post-Keynesian view and enforces the perception that monetary policy has to work via aggregate demand factors i.e. reducing income and exerting pressure on businesses' profitability.

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A recent study by Moll (1999) suggests that there does not appear to be any short-term links between monetary aggregates and real income. He (1999:40-44) also concludes that the use of broad money (M3) as an intermediate target can be questioned, since the magnitude and timing of the effects of broad money interventions are still unknown. This provides empirical support to the previous criticism of M3 as an intermediary target.

De Wet, Jonkergouw and Koekemoer (1996) estimate and evaluate an annual econometric model for monetary policy in South Africa. In the model, the Bank rate has been utilised as an indication of expected future economic conditions. No other expectation variables or proxies thereof have been defined or included in the model. De Wet et al. (1996: 585) also maintain that the Bank rate represents the only real brake on money creation, thereby implying that the Bank rate is the key policy instrument. This, in a nutshell, confirms that monetary policy can be modelled as a reaction function for the Bank rate and that expectations regarding monetary policy are in essence expectations regarding this interest rate.

With regard to inflation, an extensive study was carried out by De Wet (1987), who provides a single equation specification of inflation with the annual percentage change in excess demand, wage per unit output and the import price deflator as regressors. All regressors were highly significant in explaining percentage changes in the CPI (De Wet 1987: 174-181, 272-274). Furthermore, *'na die intree van n'resessiefase, word die groei in oorskotvraag negatief wat*



*dan afwaartse druk op pryse behoort uit te oefen.... Die groei in die kostefaktore bly egter positief tydens n' resessie, alhoewel die groeitempo afneem. Gevogliks hou die kostefaktore aan om positiewe opwaartse druk op pryse uit te oefen* '(De Wet 1987: 176). These results are encouraging in that excess demand and therefore monetary policy can exert significant direct pressure on the inflation rate. The latter is therefore not just subject to exogenous cost factors. De Wet (1987:177) further observe that the sum of the cost factor's elasticities and the excess demand elasticity are approximately equal. This suggests that in order to reduce inflation, the percentage decline in demand has to exceed the percentage increase in costs.

#### **5.4. CONCLUSION**

With fiscal spending dictated by the budget process, stabilisation policy in South Africa has primarily been the responsibility of the SARB. Two broad schools of thought prevail regarding the transmission mechanism of monetary policy. The Monetary School, arguing that causality is essentially from money supply growth to inflation, is propagating the abstention of active intervention and the consistent control of the money supply. The money supply is therefore the key policy instrument. The Post Keynesian School, on the other hand, emphasises the exogenous nature of inflationary pressures, suggesting causality from inflation and the real economy to the money supply. In this case, monetary policy is aimed at controlling the price liquidity, i.e. interest rates. These two schools of thought are of relevance to South Africa as the SARB has set money supply guidelines in accordance with the Monetary School yet at the same time,



it provides unlimited accommodation by setting the cost of liquidity.

Monetary policy of the SARB finds its primary mission in maintaining the domestic and international value of the rand as initially outlined by the recommendations of the De Kock Commission. To achieve this task, the policy instrument is given by the Bank rate and the intermediary goal is the curtailment of the money supply. The Bank hopes to influence money supply by determining the cost of accommodation to commercial banks and thus demand for credit.

The De Kock Commission introduced a more market-orientated approach of monetary policy in South Africa. Instead of credit ceilings and other direct measures, the focus has been on open market transactions with the aim of achieving overall financial stability. The shift away from active monetary policy for stabilisation purposes was in line with a global redirection of monetary policy towards a more Monetarist methodology of predictable central bank policy aimed at financial stability. The adherence of this approach has been enforced with the governance of Dr. Stals.

Due to the consistency of the SARB's policy, a policy reaction function is capable of capturing the functioning of monetary policy in South Africa. Given this transparency, economic agents can be expected to form their expectations of interest rate changes on such a policy reaction function. This necessitates the incorporation of RATEX to overcome the Lucas critique whenever monetary

policy simulations are evaluated.

With regard to the ultimate goal of price stability, it needs to be stated that monetary policy has several channels to prove its effectiveness even though the inflation process in South Africa is claimed to be primarily cost-push in nature.



## CHAPTER VI: SPECIFICATION OF STRUCTURAL EQUATIONS AND EXPECTATIONS PROCESSES

### 6.1. INTRODUCTION

A structural econometric model is an empirical interpretation of economic relationships on the basis of economic theory. However, as Wallis and Whitley (1991:157) point out, economic theories, whether micro or macro, are in general incomplete and empirical implementation of these theories requires supplementary specification. These specifications usually find their origin in the properties portrayed by the data. A macro model is therefore always a reflection of theory and actual data. *There must be a theoretical basis for equation specification, and there must also be a close correspondence with reality'* (Klein 1987:416).

The current model is built on theoretical principles, institutional factors and data properties. In Section 6.2, a broad overview is given of the model's main components. Section 6.3 provides a more detailed discussion of the model's specification in terms of its structural equations and expectation processes. Where appropriate, relevant references to economic theories and alternative empirical specifications will be provided.

### 6.2. A BROAD OVERVIEW OF THE MODEL'S STRUCTURE

Mainstream macroeconometric models are specified around the income-expenditure national accounts identity which implies that output (and

employment) is primarily demand determined. In the early 1970's, these models came under severe criticism due to their poor forecasting performance. As a result, greater emphasis has been placed since on modelling the supply side. This tendency originated partly from the desire to explain aspects such as the cost push inflation initiated by the oil shock of the 1970's but also from the desire to provide a more extensive macroeconomic framework and to achieve a proper treatment of markets incorporating both demand as well as supply factors<sup>1</sup> (Whitley 1994:41-46, Wallis and Whitley 1991:158). A further tendency has been the utilisation of stock rather than solely flow concepts. This resulted from the impact of the new classical approach in macroeconomic analyses and among other things, has lead to the inclusion of wealth as a determinant of private consumption.

At the heart of the more modern approach to the supply side lies the wage and price sector<sup>2</sup>. In the classical tradition of competitive markets, the focus fell on production functions<sup>3</sup>, the availability of production factors (such as capital accumulation and growth in the labour force) and technological progress to derive the conventional aggregate supply curve. This model was complemented by the

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<sup>1</sup>. In the UK, the increased emphasis on the supply side was enforced by a rapid increase in unemployment during 1980 -81 and the Conservative Government's supply side policies which focused on improvement of incentives and the creation of more competitive conditions (Thomas 1993:411, Wallis and Whitley 1991:158).

<sup>2</sup>. For a comprehensive discussion on supply side modelling, see Nickell (1988). For a detailed illustration of supply side modelling for the 7 major OECD economies, see Turner, Richardson and Raufflet (1996).

<sup>3</sup>. An inverted production function can then be used to derive the level of employment.



Phillips curve and the resulting natural rate of unemployment to link price changes to wage changes and possible output responses<sup>4</sup>.

In the UK, the focus has shifted to a more detailed analysis of labour market imperfections and more specific to how wages are determined. According to Nickell (1988: 205), wages can be determined by four mechanisms namely demand and supply, the firm, trade unions or collective bargaining. The latter is central to Layard and Nickell's (1985) approach of imperfect competition and bargaining, which is at the forefront of modelling wages in the UK. This approach is outlined by Nickell (1988:205-206, 215-217) and Whitley (1994: 97-100).

The second component of the supply side refers to prices. These are generally modelled as a mark up over cost. A factor representing demand or capacity utilisation is also often included. The final component of the supply side is the price of foreign currency, i.e. the exchange rate which is generally modelled on the basis of interest rate or purchasing power parity. It will tend to have an effect on the domestic price level and international competitiveness and thus on wages and employment.

The model presented below can be divided into demand and supply components. The demand sector consists of the conventional aggregates of consumption, investment, government, exports and imports. With regard to the supply side, the

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<sup>4</sup>. The concept of a non accelerating rate of unemployment, or NAIRU, has found a lot of support, particularly in UK modelling (see Whitely (1994: 100 - 110)).

primary components are wages, prices, the exchange rate and employment. The current study does not attempt to model the labour market or production capacity explicitly. However, a Phillips curve type relationship between unemployment or capacity utilisation and price increases is acknowledged in the model.

The third pillar of the model refers to monetary conditions. Its key components are the Bank rate, short and long-term interest rates, international capital flows and the resulting balance of payments as well as the demand and supply of money. A key characteristic is the fact that the money supply is determined predominantly by the demand for credit.

### **6.3. DESCRIPTION OF THE BUILDING BLOCKS OF THE MODEL**

#### **6.3.1. BLOCK 1: COMPONENTS OF DEMAND**

From the national accounts identity, there are five major demand components, namely consumption, investment, exports, imports and current expenditure of government. All of these are modelled in real terms and each of them will be discussed separately.



### 6.3.1.1. Private Consumption Expenditure

Total real private consumption is subdivided into durable, semi-durable and non-durable consumption as well as services<sup>5</sup>. All equations feature an income variable, which is either the real disposable wage bill or real disposable income. In addition, a wealth variable has been introduced on the basis of the life cycle hypothesis. This hypothesis states that individuals plan their expenditure not on income received during the current period but aim at utility maximisation over their entire life span (Ando and Modigliani 1963:56 –57, Thomas 1993:252-257).

The inclusion of a wealth variable is in line with current modelling practice. Most models of the UK such as the NIESR, LPL and LBS models include a variable for total, housing or financial wealth in their consumption functions<sup>6</sup>. Whitley (1994:83) maintains that an inflation term is often used as a proxy for wealth or rather as indication of the loss of real wealth. Alternative specifications use an inflation-adjusted measure of real income. In some models, a further distinction is made between financial and physical or housing wealth (Whitley 1994:84). Also,

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<sup>5</sup>. It is almost universal practice to model the disaggregated equations and then derive aggregate consumption as the sum total. An exception to this is found in the KVARTS model of the Norwegian economy where a total consumption function is specified in terms of real disposable income and real increase in credit. Total consumption is then allocated to seven subcategories according to estimated equations with necessary coefficient constraints imposed (Biørn, Jensen and Reymert 1987 : 87 - 88).

<sup>6</sup>. Other models that follow Modigliani's approach are for example, the Federal Reserve Board's model of the US economy (Brayton and Mauskopf 1985: 182 - 186) or the Murphy model of the Australian economy (Murphy 1988: 179 - 180 ).



in the model of the Bank of England (1999:46), unemployment is explicitly included as a proxy for consumer confidence.

In the fiscal policy model of the South African economy (Smit and Fourie 1995: 2), wealth is defined as the sum of the real broad (M3) money supply and the stock of private residential property. This variable is found in the specification of all four types of consumption expenditure. Similar to the SAMMSON model (1998: 17-18), the current study uses the real money supply as a proxy for wealth.

All the consumption equations feature an interest rate as a determinant. In the case of semi-durable consumption, the expected future mortgage rate is used. All interest rate coefficients show a negative sign, which is in line with all of the evaluated South African models<sup>7</sup>. The negative sign shows that the substitution effect between consumption and savings appears to dominate over the income effect resulting from higher returns on savings. Higher interest rates would also imply a capital loss on securities, which negatively affects wealth<sup>8</sup>.

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<sup>7</sup>. These refer to the quarterly and annual BER models (Smit and Meyer (1985), Smit and Pellissier (1995)), the Fiscal model (Smit and Fourie 1995) as well as the Reserve Bank's quarterly model (Pretorius and Knox (1995:35-36)). In the specification of consumption in the World Bank's Model (SAMM), no interest rate was included (Fallon and De Silva 1994: 194 - 199)

<sup>8</sup>. According to Keynes (1942:93,94) *'the total effect of changes in the rate of interest on the readiness to spend on present consumption is complex and uncertain, being dependent on conflicting tendencies, since some of the subjective motives towards savings will be more easily satisfied if the rate of interest rises, while other will be weakened ....The usual type of short period fluctuation in the rate of interest is not likely ...to have much direct influence on spending*



Fallon and De Silva (1994:195) state that '*Economic and political uncertainty is probably a powerful factor in South Africa in explaining consumption patterns...*'. This conclusion is confirmed by the inclusion of several dummy variables in the SAMMSON's and current study's consumption functions (SAMMSON 1998:17-18)

### **6.3.1.2. Investment**

Real gross domestic fixed investment is subdivided by type of organisation into gross domestic investment by public authorities, public corporations and private business enterprises. Only the last of these three is treated endogenously. Private fixed investment is further subdivided into non-residential and residential investment.

There are two variables that stand out in the private non-residential investment equation. These refer to changes in demand or output and changes in relative prices. This specification is derived from the accelerator model and the neo-classical models respectively. The accelerator model considers investment as an adjustment to a desirable capital stock. This capital stock is dependent solely on output under the assumption of a fixed capital output ratio. The neo-classical model, on the other hand, is based on an explicit model of optimisation. Berndt (1991:224-265) provides a detailed discussion of these investment models. He (1991:270-277) also quotes a study by Kopcke in which the different models are

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*either way.... Perhaps the most important influence, operating through changes on the appreciation or depreciation in the price of securities and other assets'.*

compared and evaluated. From this study Berndt (1991:276) concludes that no investment model consistently dominates its competitors empirically. Thus, although often criticised for assuming a constant capital output ratio and thereby ignoring profit maximising principles, the accelerator model cannot be regarded as inferior.

Whitley (1994:118) maintains that earlier macro models tended to adopt the accelerator approach whereas more recent attention focused on optimisation and therefore neo-classical models. However, he concludes (1994:120) that output still plays an important role in the determination of fixed investment and that aspects such as the real capital costs or relative factor prices on their own are insufficient. Thus, although there are numerous other theories to investment behaviour, the accelerator model or at least changes in output as an explanatory variable continuous to be found in most models.

Fallon and De Silva (1994:184) reject the assumptions of the neoclassic model<sup>9</sup> and conclude that private investment behaviour is primarily determined by the growth in demand and relative factor costs. In the case of a developing country, a number of additional factors such as exchange rate shortages, financial repression or the complementary of government investment could play a role. In a survey on private investment in developing countries, Rama (as quoted by Fallon and De Silva 1994:186) concludes that aggregate demand proves an important variable

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<sup>9</sup>. The Neo Classical model of investment is based on an explicit model of optimisation behaviour. This model assumes a perfect market for second hand capital goods as well as for input and output markets (Berndt 1991:242-245)



whereas public investment is ambiguous because of crowding in and out effects. Furthermore, proxies of relative factor prices are rarely insignificant and dummies are often used to represent economic instability.

Greene and Villanueva (1991) conclude in their empirical study on investment behaviour in developing countries that '*real interest and economic growth rates, the domestic inflation rate, external debt burdens..., and to a lesser extent, the public investment rate have all been significant determinants of private investment rates ... during the post 1974 period*'. Their regression results show that public investment has a positive influence on private investment and is therefore complementary (1991:51). Sundararajan and Thakur (1980) have carried out an earlier but more in depth analyses of the positive and negative effects of public investment in developing countries. Their private investment functions<sup>10</sup> include among the conventional variables the difference between domestic savings and public investment (1980:832,838,840). The latter's coefficient is positive and highly significant which supports the crowding out effect. However, their simulation results show that although crowding out is the short run effect, in the long run, public investment exerts a positive influence on private investment.

For the specification of real non-residential investment in this model, the accelerator model was used as a starting point. Other variables included are the

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<sup>10</sup>. These functions form part of a model estimated for India and Korea.

long-term interest rate, representing the cost of capital, and a lagged dependent variable<sup>11</sup>.

Fallon and De Silva (1994:191-192) use the real interest rate as a cost factor in their South African specification of private residential and non-residential investment. Although they (1994:191) mention expected real disposable income as an important variable, no explicit expectation variable is included in their specification. In the current study, the expected future mortgage rate features as an explanatory variable in the specification of real private residential investment. This is based on the hypothesis that private residential investment is constrained by the availability of finance and the ability to service debt. An expected higher interest rate would result in a greater financial constraint on households and therefore lead to a reduced residential investment. This is particularly true for South Africa, where mortgage loans as a percentage of personal disposable income have increased from 25 per cent in 1981 to 33 per cent in 1993 (Van der Walt and Prinsloo 1995:6). Other variables found in the specification of residential investment are real disposable income, relative prices and a trend factor<sup>12</sup>.

Smith and Van der Heever (1995) specified changes in real inventories as a function of aggregate sales, the level of inventories, the prime rate as well as the

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<sup>11</sup>. An attempt was made to utilise relative prices as measured by the ratio of interest rates to real unit labour costs rather than only interest rates. However, the current specification provided superior single equation and simulation results.

<sup>12</sup>. This trend part captures the decline in real house prices since the mid 1980's.



real effective exchange rate. In this model, changes in real inventory are modelled as a function of interest rates and changes in the domestic demand components.

#### **6.3.1.3. Trade**

There is some controversy surrounding the equation for exports. On the one hand, the volume of exports can be interpreted as an equation reflecting foreign demand for domestic goods. However, a change in the volume of exports need not always arise from a change in the demand for these goods where the latter is caused by changes in, primarily, foreign income. The export volume refers to the demand and supply at equilibrium. Thus, the volume of exports can also be modelled as a supply equation with explanatory variables given, for example, by international competitiveness and domestic export capacity.

Whether export volume should be seen as demand or supply driven depends on what causes the change in export volumes. Thus, it centers on the specification of the export equation. Usually, the export equation includes variables representing competitiveness as well as factors affecting foreign demand so that it cannot be defined as either a supply or demand equation. A similar argument can be made with regard to imports. It is a demand equation if imports are specified as a function of domestic income but it is a supply equation if import volumes are explained by domestic capacity utilisation. Again, both variables are usually found in equations of import volume.

The supply factors of exports of a developing country include domestic prices, the growth of GDP, taxes and or subsidies (Bond 1985:57-59). The primary demand determinants include the demand for imports in developed countries and prices of the importing and/or competitor countries. Bond (1985:60-65) specifies separate supply and demand equations for exports. With the help of an equilibrium condition, he then derives a single reduced form equation explaining exports as a function of the real effective exchange rate, GNP of the importing country, deviations from an output trend and a variable explaining other factors. The variable representing deviations from an output trend is initially found in the supply equation and gives an indication of excess capacity or output. Thus conventional exports and imports equations can be seen as reduced form equations in that they are based on a structural demand and supply equation and represent the combined effects on the equilibrium volume (Whitley 1994:89-97).

Fallon and De Silva (1994: 200-202) model South Africa's non-gold exports as a function of foreign demand (industrialised countries production index) and a price ratio of export prices to foreign prices<sup>13</sup>. South Africa's imports of non-oil goods was modelled as a function of local demand (GDP), a price ratio and a trend for structural long term changes in South Africa's import propensity. In the fiscal model (Smit and Fourie:1995), domestic capacity utilisation is also included in the specification of merchandise imports while real exports are explained in a similar fashion to the SAMM model. The SAMMSON model follows a similar

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<sup>13</sup>. Kahn (1974:691-692) provides early empirical support for the conclusion that prices and real income play an important role in the determination of exports and imports of developing



specification but includes numerous dummy variables to take account for the structural changes that have occurred since the second half of the 1980's (SAMMSON 1998:21-23).

In the current study, real imports are subdivided into real merchandise imports and real imports of non-factor services. Merchandise imports are explained by real domestic demand as well as domestic and foreign prices. Imports of non-factor services are modelled as a function of real merchandise imports. Nominal imports of factor services are treated as exogenous.

Real exports are subdivided into real merchandise exports, real exports of non-factor services and gold exports. Real merchandise exports is explained by foreign demand (G7 GDP) as well as the real effective exchange rate. Smal (1996:33) found a significant negative coefficient for domestic demand in a South African export equation referring to manufactured exports only. The reason for this inclusion is based on the argument that South African exporters tend to increase their exports if domestic demand is slack. This conclusion could not be supported in this model. Exports of non-factor services are explained by real merchandise exports and imports. Nominal exports of factor services and real gold exports are treated as exogenous.

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countries. For industrialised nations, it is almost universal practice to model trade as a function of relative prices and demand. For an example, see Bank of England (1999:50-52).

## **6.3.2. BLOCK 2: GOVERNMENT FISCAL BLOCK**

### **6.3.2.1. Interest Payments**

Current and capital expenditure of general government is treated as exogenous. It is only the interest payments that are endogenous to the model. Government has several options to finance its deficit. It can borrow locally in the capital market (through the issuing of bonds) or the money market (TB funding) or it can borrow from foreign capital markets. The possibility of borrowing from the central bank, i.e. printing money, is not considered a feasible option.

The amount by which the level of TB's is raised, as well as the amount of foreign borrowing, is predetermined with respect to a particular borrowing requirement. The remaining borrowing requirement is then funded through local bond issues<sup>14</sup>. In the current model, only local bond and TB issues are considered when determining interest payments.

In this model, government interest payments are a function of interest payments in the previous year plus interest on new stock issued. The latter consists of interest on government bonds as well as interest on the net increase of Treasury Bills. The increased interest on TB's is determined by the additional TB funding which is

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<sup>14</sup>. For example, the net borrowing requirement of the National Government for 1997/98 amounted to around R23 billion while loan redemptions amounted to R12 billion, which brought the gross borrowing requirement to around R35 billion. This was financed by raising the average TB balance by R2 billion, net foreign borrowing of R4 billion and the rest through government bond issues in the local capital market (Budget review 1998:3.25).



exogenous and the average TB rate, which is determined by the Bank rate. The interest payments on new government bonds is determined by the coupon rate as well as the size of the new stock which depends on the deficit as well as the discount at which new stock is issued<sup>15</sup>. Any coupon difference between maturing stock and new stock is ignored<sup>16</sup>. Together with the fact that foreign borrowing is ignored, this induced a margin of error in the calculation of government interest payments which necessitates the inclusion of an error term.

#### **6.3.2.2. Current Revenue**

With respect to government revenue, a distinction is drawn between tax revenue and other revenue. Tax revenue is endogenous and subdivided into direct and indirect taxes.

According to Smal (1995:1), there are three approaches to the modelling of tax revenue. The first specifies an equation with independent variables that are significantly correlated with tax revenue. Kahn and Knight (1981) built a developing country model where tax revenue is modelled in such a way. Tax revenue is explained by a behavioural equation consisting of nominal income and a lagged dependent variable. A much more complex approach is to model tax revenue explicitly in which case the tax model would have to be an adequate

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<sup>15</sup>. The equation referring to new stock issues is obtained from the debt model of the Department of Finance and is also found in the Fiscal Model (Smit and Fourie :1995)

reflection of the tax structure. In the third approach, tax revenue is simply a fraction of an appropriate tax base:

$$TR = \Psi TB$$

where

$TR$  = Tax revenue

$TB$  = Tax base

$\Psi$  = Tax rate

For direct taxes, the tax base would be corporate or personal taxable income and for indirect taxes, a consumption aggregate is appropriate. In the absence of a single statutory tax rate, the latter can be approximated by  $TR/TB$ . However, given that  $TR$  refers to actual receipts, this tax rate should be seen as the effective tax rate<sup>17</sup>. This third approach is used in a number of South African macro models<sup>18</sup> and has also been used for the current model. This model distinguishes between direct personal and direct corporate taxes as well as indirect taxes, which include VAT and custom revenue.

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<sup>16</sup>. This could be regarded as a major error if the coupon rate were to respond quickly to market yields. This is, however, not the case.

<sup>17</sup>. Any change in this rate is either the outcome of a change in the statutory tax rates and or a change in the efficiency of revenue collection.

<sup>18</sup>. Examples are the BER annual econometric model (Smit and Pellissier : 1995), The Fiscal Model of South Africa (Smit and Fourie: 1995), the Reserve Bank's econometric model (Small : 1995) as well as the SAMMSON model (1998:55).



### **6.3.2.3. Deficit and Macroeconomic Implications**

Dissaving by the government is the difference between current revenue and current expenditures and is therefore also an endogenous variable. The deficit before borrowing is derived from general government's dissaving and capital expenditure.

The deficit feeds into long-term bond yields. In the absence of higher tax rates, increased government expenditure will raise the deficit and thus government's claim on domestic savings. This results in higher yields, which will crowd out private investment spending. A higher yield will, in turn, raise government interest payments. This will be the case immediately if the coupon rate is adjusted or gradually as the discount will induce a wedge between borrowing requirements and required new stock issued.

A change in the Bank rate will affect government's interest payments directly via the yield on treasury bills. Depending on the response of long term rates, it will also affect the cost of raising funds on the capital market. A more restrictive monetary policy will also reduce real economic activity and thus tax revenue. However, long-term rates are likely to respond positive in the light of expected lower inflation.

### **6.3.3. BLOCK 3: SUPPLY SIDE AND PRICES**

The major components of supply include prices, the exchange rate as well as wages and employment.

#### **6.3.3.1. Prices**

It is a fairly standard approach in macro models to estimate a critical price equation from which other prices are then derived. In the case of the SAMM model, the critical price equation is that of producer prices which are modelled as a mark up over unit labour cost and a lagged dependent variable (Fallon and De Silva 1994:204-205, 252). Existing spare capacity, as derived from a production function is also included to represent the influence of demand on the mark-up over costs. Import prices are derived from foreign prices multiplied by the nominal exchange rate (Fallon and De Silva 1994:205-206, 252). In the annual BER model, all price equations center on the PPI and the consumption deflator (Smit and Pellissier 1995:6, 17-20). In the quarterly model, it is the deflator of gross domestic expenditure (Smit and Meyer 1985:110-112, 126-126) while in the Fiscal Model it is the private consumption deflator and the domestic component of the PPI that serve as basic price indices (Smit and Fourie 1995:3).

The basic price equations in the current study are the producer price index and consumption deflator. Both are modelled as a mark up over costs and the specification includes unit labour costs as well as import prices as explanatory variables. Unemployment is also included as a measure of capacity utilisation. All



other domestic price variables are derived from the producer price index. With regard to the investment and government expenditure deflators, import prices and unit labour costs were respectively added to the producer price index as explanatory variables. The consumer price index is explained solely by the producer price index. The GDE deflator is derived from consumption, investment and government expenditure deflators in accordance with the national accounts identity<sup>19</sup>.

Import prices are modelled as a function of foreign prices as measured by the CPI of the G7 countries and the nominal effective exchange rate while export prices are explained by a function of the domestic producer price index and the nominal effective exchange rate.

#### **6.3.3.2. Exchange Rates**

The structural modelling of exchange rates since the collapse of the Bretton Wood system has been a difficult task. Meese and Rogoff (1983) found that structural models of exchange rate behaviour<sup>20</sup> could not outperform a simple random walk model in forecasting. In an assessment on exchange rate modelling, Isard (1988:197) goes even as far as concluding that *the empirical modelling of*

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<sup>19</sup>. This specification should actually be an identity with the sum of the coefficients equal to one.

<sup>20</sup>. These models include the Flexible-Price Monetary Model, the Sticky-Price and Real Interest Differential Monetary Models as well as the Portfolio Balance Model to mention the more popular ones (MacDonald and Taylor 1992: 2 - 9).

*exchange rates over the past decade has been largely a failure*'. He ascribed this in particular to the assumption of uncovered interest parity (UIP) and or purchasing power parity, which have been the major foundations of exchange rate modelling. Isard (1988:188) concludes that *'evidence appears to reject persuasively the assumption of uncovered interest parity and the closely related notion that exchange risk premiums are quantitatively unimportant ...'*. Similarly, Meese and Rogoff (1985) found no cointegration between the real exchange rate and real interest rate differential suggesting therefore that the variability of the real exchange rate cannot be related to the variability of real interest differentials. In a more recent study, Meese (1990:132) confirms this finding by concluding that *'... models of exchange rates based on macroeconomic fundamentals...cannot explain exchange rate movements in the post-Bretton Woods era significantly better than a naive alternative such as a random walk model '*.

Within the context of a developing country, the appropriateness of UIP can be further questioned if the risk factor is considered as being of far more importance in developing countries than in developed ones. This factor could overshadow positive interest rate differentials due to high and varying risk premiums and therefore confirm Isards findings in the case of developing countries' spot rates.

For the UK, Fisher, Turner, Wallis and Whitley (1990) specify what they call a preferred exchange rate equation. The spot rate is modelled as a function of current and lagged prices and interest rate differentials as well as a measure of risk premium. This specification is the general form within which other specifications of UK models are nested and is based on UIP expressed in real terms. In the



SAMM model (1994:218), PPP dominates the specification of the rand/US\$ exchange rate. The spot rate is derived from a constant real exchange rate so that the nominal rate is simply adjusted by the inflation differential of the previous period.

The modelled exchange rate in this study is the rand/US\$ spot rate. Together with other spot rates and relevant consumer price indices, the nominal and real effective exchange rates are derived<sup>21</sup>. Other rand spot rates are determined from exogenous cross rates.

The rand/US\$ spot rate is specified as a function of the expected South African and US CPI index, the expected Bank rate and US Libor rate as well as changes in reserves owing to balance of payments transactions. In the SAMM model (1994:190, 195, 218) the inflation differential (the ratio of local to foreign CPI) is used as a proxy for South Africa's risk factor in numerous equations<sup>22</sup>. The expectation regarding the future CPI used in the rand/US\$ specification of this study could therefore be interpreted as expected financial risk. Furthermore, given that expectations are model consistent, the exchange rate will respond to price movements and thus support purchasing power parity in the long run. That long run purchasing power parity cannot simply be ignored is supported by MacDonald

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<sup>21</sup>. The effective rate refers to the weighted average exchange rate as defined by the SARB and includes the following four currencies (weights in brackets): US dollar (51,7), British pound (20,2), Deutsche mark (17,2), Japanese yen (10,9) (SARB 1997:S-99). Note, however, that with the introduction of the Euro, the SARB's weights have changed since early 1999.

<sup>22</sup>. These refer to equations explaining consumption, investment and the TB rate (Fallon and De Silva 1994:195 - 196, 190 - 191, 218).

(1995) who concludes that there is considerable evidence supportive of a long run relationship between relative prices and exchange rates in the sense that they do cointegrate<sup>23</sup>.

The rand/US\$ spot rate is also determined by the expected Bank and US Libor interest rates one period ahead. Expectations regarding monetary policy in the future will therefore influence the current level of the exchange rate. Expectations of a tighter monetary policy should lead to a strengthening of the currency as accelerated capital inflows should materialise. This is supported by the equation explaining capital movements on the balance of payments. Similar to the exchange rate, these are explained by the expected interest and inflation rate differential between South Africa and the US.

#### **6.3.3.3. Wages and Employment**

Formal employment in the non-agricultural private sector is subdivided into private sector and public sector employment. It is only private sector employment that is endogenously determined in the model.

In their discussion on the supply side, Whitley and Wallis (1991:158) maintain that *labour demand depended previously on output and varies time trends proxying productivity growth... since the mid 1980's the real wage has been*

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<sup>23</sup>. His study focused on the spot rates of European currencies against the US dollar as well as the Canadian and Japanese spot rates.



*included* [in the employment equation]. In the current study, formal employment in the private sector is modelled as a function of domestic private consumption, gross domestic fixed investment, the real wage rate, a lagged dependent variable as well as a time trend taking account of labour saving technology.

The modelling of wages in the SAMM (1994:206-207) model distinguishes between skilled and unskilled workers. For both equations, a lagged dependent variable is included. For skilled workers the specification is fairly standard with productivity and unemployment as key regressors. In this study the real wage rate is determined by labour productivity, the level of the unemployment rate and a trend. This specification, together with the employment equation, contains the central functions determining private income.

The real wage bill is derived from the real wage rate and employment. Labour supply is considered exogenous to the model. Unemployment, defined as the difference between labour demanded as reflected by employment and labour supply, is endogenous.

#### **6.3.4. BLOCK 4: MONETARY COMPONENTS**

The monetary components of the model include the Reserve Bank's reaction function for the modelling of the Bank rate as well as other short-term interest rates such as the prime, mortgage and TB rate. The average yield on government stock longer than 10 years was used as the long-term interest rate. The money

supply is the last component and is derived from the modelling of the demand for credit as well as the balance of payments.

#### **6.3.4.1. Interest Rates**

##### **6.3.4.1.1. *The Bank Rate***

The statement that a regression equation should be specified on the basis of economic theory receives new meaning when the task involves the building of a policy reaction function. The specification has to be an adequate representation of monetary policy and in that regard has to reflect the goals, intermediary objectives and responsibilities of the Reserve Bank.

As discussed in detail in Chapter V, the policy reaction function of this study has real credit growth, inflation and the exchange rate as key explanatory variables. Real credit growth provides an indication of possible excessive growth in the demand for liquidity, which, given the endogenous nature of money, has direct implications for money supply guidelines.

As explained above, instead of using the current and/or capital account of the balance of payments as an explanatory variable, the real effective exchange rate is used. The sign of this coefficient should be positive. If the real exchange rate depreciates substantially (e.g. as a result of a net deficit on current and capital account), the Reserve Bank will exert upward pressure on the Bank rate, an aspect that has become particularly evident during the 1980's and 1996. The motivation is



given by possible inflationary pressure and thus expectations of further depreciation or by the need for foreign reserves. If the real exchange rate appreciates and therefore leads to increased foreign reserves, South Africa's competitiveness is negatively influenced but on the other hand, foreign reserves accumulate satisfactory. Both of these aspects suggest a reduction in the bank rate.

#### ***6.3.4.1.2. Short and Long Term Interest Rates***

The modelled short-term interest rates include the prime overdraft rate, mortgage rates as well as the TB rate. All of them are modelled as a function of the Bank rate<sup>24</sup>.

The long term interest rate is explained by expected future price changes, capital account considerations, changes in the money supply as well as current dissaving of government. The expected future price change can be seen again as a proxy for expected financial risk. The inclusion of expected inflation implies that a tightening of monetary policy through higher short-term rates will put downward pressure on the yield as inflation expectations are adjusted downwards. In the Fiscal Model, the ESKOM rate is modelled as a function of previous rather than expected price changes, the balance of payments as well as the BA rate (Smit and Fourie: 1995).

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<sup>24</sup>. The almost mechanical derivation of money market rates from official rates is not uncommon in model building. See for example, the model of the Bank of England (1999:40-41).

### 6.3.4.2. Money demand and Supply

#### 6.3.4.2.1. *Defining Components of the Money Supply*

The question of money demand and supply can be approached from two sides, either from the side of notes, coins and deposits or from the side of loan requirements. The discussion in Chapter V has shown that the demand for credit appears to play a particular important role in linking money supply increases and cost push inflation factors. In this study, the money supply is modelled on the basis of the flow of funds model:<sup>25</sup>

$$D(MS) = [PSBR-D(PLG)] + D(LPS) + D([OA-NDL]) + F^{26} \quad (5)$$

where

$D(MS)$  = Changes in the money supply (M3)

$[PSBR-D(PLG)]$  = Changes in net claims on government sector

$D(LPS)$  = Changes in claims on the private sector

$D([OA-NDL])$  = Changes in net other assets and liabilities

$F$  = Changes in the cumulative flows of net foreign assets

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<sup>25</sup>. For a detailed discussion on how the following equation is derived, see Gowland (1985 : 110-116).

<sup>26</sup>. This relationship is reflected in table KB126 of the SARB Quarterly Bulletin.



From this equation, it follows that a change in  $M3$  is caused by four components, each of which require brief explanation:

**PSBR -D(PLG)** : The Public Sector Borrowing requirement (PSBR) is the amount the government needs to borrow. This is accomplished by the selling of Treasury Bills and long term stock. These bonds are either bought by the private sector or by the Reserve Bank. In the latter case, the Reserve Bank credits the government's accounts against its own, resulting in an increase of money equivalent to the borrowing. In the case of the private sector, it leads to a change in the private loans for government. If private agents (e.g. insurance companies) buy the Treasury Bills, their account at commercial banks will be debited and the government's account at the Reserve Bank credited, so that no change in the money supply occurs. The difference (PSBR -D(PLG)) is the amount by which the Reserve Bank and the banking sector as a whole have to accommodate government's borrowing needs and therefore represents an increase in the money supply. This variable is not under the control of the Reserve Bank as it depends primarily on the government's need for funds as well as the markets willingness to absorb new government debt issues. It is equivalent to the Government's demand for final credit from the banking sector.

**D(LPS)** : This is the biggest factor determining changes in the money supply. Money supply is increased in that every new loan results in an equivalent deposit. It is in that context that Post-Keynesians argue that the demand, and consequently supply of money is credit driven. This variable is endogenously determined by the model's demand for credit functions. Consequently, it is this



variable that the Reserve Bank attempts to manipulate through interest rate adjustments. Its modelling is therefore a key ingredient in that it will determine the extent to which interest rate policy of the Reserve Bank exerts a direct impact on money demand and to what extent the influence is indirectly, via the income determinant of the demand for money.

**D([OA - NDL])** : Open market transactions of the Reserve Bank influence the money supply in that should the Reserve Bank sell Treasury Bills into the market, private agents' accounts with commercial banks will be debited while the banks account at the Reserve Bank is also debited. This effect is reflected by **D([OA - NDL])** in that the commercial bank's assets at the Reserve bank have declined with an equal amount to the decline in private agents deposits at the commercial bank. The Reserve Bank's goal in carrying out open market transaction is to enforce their interest rate policy by ensuring that commercial banks are 'in the Bank' and have to utilise the Reserve Bank's overnight loan facility. This variable does therefore not reflect a target variable<sup>27</sup>.

**F**: A final factor affecting money supply is net foreign capital movements (originating from both, current and capital account transactions). A net inflow of foreign capital increases the Reserve Banks foreign reserves. It also increases commercial bank deposits in that economic agents received funds. The assets of commercial banks have also increased in that the Reserve Bank credited their

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<sup>27</sup>. In South Africa, this money supply category includes losses and profits the SARB makes on its forward cover operations. A loss for the SARB will imply an increase in the money supply.



accounts in exchange of the foreign reserves. A net capital inflow results therefore in an equivalent increase in deposits. Although foreign capital inflow increases the money supply, such a movement will always be welcomed by the Reserve Bank to provide relief for the balance of payments constraint.

Given the previous discussion on the determinants of money supply, two components, namely LPS and F are defined as endogenous in that the Reserve Bank via its interest rate policy, attempts to influence them. F consists of two components, namely current account transactions and net unrelated capital movements. The other components of money supply growth are treated as exogenous in that the Reserve Bank has no influence over the variables and it is of no concern to policy formulation and interest rate responses.

In Kahn and Knight's (1981:15-17) model for developing countries, the money supply is modelled as the sum of the net stock of international reserves (in domestic currency terms) and net domestic credit. The latter, in term, is determined by an identity including the fiscal deficit, changes in the claims on the private sector and the previous period's domestic credit. The assumption is that all changes in the claims on government are a reflection of the fiscal deficit. For South Africa, such an assumption is unrealistic as the borrowing needs of government are primarily accommodated by the non-banking sector. This, as outlined, has no impact on the money supply.

Kahn and Knight (1981:15-17) consider claims on the private sector as an exogenous variable whereas in the current study, it is the major driving force of money supply growth.

In the SAMMSON model, an approach similar to the current study is followed in sense that the money supply is modelled in line with equation (5) (SAMMSON 1998:24-27). The money supply is therefore endogenously determined by the demand for credit, which, in the case of private credit, is a function of income and interest rates.

#### **6.3.4.2.2. Claims on the Private Sector**

There are two equations governing the demand for credit by the private, non-banking sector<sup>28</sup>. The first one refers to the more consumption driven credit and includes instalment sale credit, leasing finance and mortgage advances. Bills discounted and credit demand for investment are treated as exogenous. The second endogenous equation refers to the category Other Loans and Advances and includes predominantly corporate credit.

In line with traditional money demand equations, real GDE and the prime rate explain real consumption driven credit. The real demand for credit originating from corporate activity is also modelled as a function of real GDE while the real Bank rate has been used as a measure of the cost of finance.

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<sup>28</sup>. The following classifications are the official credit categories as stated by the Reserve Bank and listed in table KB124 of the Quarterly Bulletin.



#### **6.3.4.2.3. *The Cumulative Flow of Net Foreign Assets***

Changes in net foreign assets (F) is modelled as a function of the combined influence of the current and capital account of the balance of payments. However, there is a difference between changes in net gold and other foreign reserves of the balance of payments and the cumulative flow of net foreign assets as reported in the money supply identity of the SARB Quarterly Bulletin. This difference refers to certain net other foreign assets that are not included in the balance of payments figures<sup>29</sup>. These assets are treated as an exogenous residual item.

#### **6.3.4.3. The Balance of Payments**

Merchandise exports and imports are represented by the national account series as already explained. Also already covered is trade of non-factor services. Net Gold exports as well as factor services and transfers are exogenous.

With regard to the capital account, only long-term capital movements of the non-monetary sector are endogenous. It is modelled as a function of the US South African inflation differential. As was the case with the exchange rate, the inflation differential serves as a proxy for financial risk. The coefficient of this variable is negative, showing that relatively higher inflation in South Africa increases the risk for investors and therefore leads to capital outflow and/or reduced capital inflow.

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<sup>29</sup>. Profits and losses of the SARB's Forward Book are included in this category.

Although this specification appears to be rather simple, it provides exceptionally good results during model simulations as outlined below. It also shows how volatile capital is and partly confirms the conclusion that international interest rate differentials are of less importance in explaining exchange rate behaviour in the presence of financial risk as well as substantial risk fluctuations.

### **6.3.5. EXPECTATION EQUATIONS**

It was pointed out in Chapter III that the instrumental variable equations serve two purposes. Firstly, they assist in the estimation of the structural equations. Secondly and more important, they will be used as the rational expectations generating equations. While all of the following equations were already used for the structural estimation, they are presented here as structural equations concerning expectations. These equations differ from the ones used for estimation purposes in that in the case of the latter, the emphasis has been on efficient estimator properties whereas now, the purpose is to ensure that the forecasts of these equations classify as weak rational expectations. A satisfactory classification, as already pointed out, refers to aspects such as the presence of cointegration between forecasts and actual values as well as the adequate incorporation of the model structure.

#### **6.3.5.1. Endogenous Variables**

Model consistent expectations are formed on the Bank and mortgage rate as well as the inflation rate.



#### **6.3.5.1.1. *Consumer Price Index and Inflation***

Expectations of the CPI are modelled for the current as well as future period. The expected inflation rate is modelled as the percentage change of the expected CPI one period ahead and the corresponding actual CPI three quarters lagged.

The expected CPI for the current period is modelled as a function of import prices, unit labour costs and a lagged dependent variable. In a similar fashion, the expected CPI one period ahead is modelled as a function of the expected current CPI, unit labour costs and import prices.

In the developing country model of Kahn and Knight (1981), adaptive expectations are used for current expectations of inflation. With regard to South Africa, Pretorius (1994) specified a number of expectation processes. Besides a distributive lag and an adaptive expectation model, he also specifies what he calls a rational expectation model for expectations of the current period. Rational expectations were modelled as a function of lagged growth in the money supply, lagged import inflation and one quarter lagged inflation (Pretorius 1994: 32). A structural expectation process has therefore been specified and incorporated into the macro model. While this is similar to the approach of this study, the expectations process bears no resemblance to the structural equation explaining inflation in the macro model, which is based on a specification of mark up over cost. On theoretical grounds, the classification of such expectations as rational can therefore be questioned. Also, no attempt is carried out to test for weak RATES through, for example, cointegration tests.

In a study on forecasting performances of inflation models of South Africa, Pretorius and Van Rensburg (1996)<sup>30</sup> conclude that time series specifications performed better when the inflation rate is relatively stable while structural specifications were able to explain the turning points better. A fine balance is therefore required in the specification of an equation that provides good short term forecasts/expectations yet reflects the structure of the model adequate enough to be classified as a model consistent expectation process<sup>31</sup>.

Pretorius and Smal (1994) estimated 4 quarter percentage changes in the average nominal remuneration per worker (nominal wage rate) as a function of amongst other variables, the expected current price level which is explained by growth in M3 and changes in output volumes. According to this specification, the nominal wage bill would be determined by current expectations on prices rather than by future expectations. Such a specification can be criticised on grounds of Friedman's fooling model in that workers have persistently wrong expectations regarding their real wage. This is not so much the outcome of an inadequate expectation specification but rather because future nominal wages are related to the expected current CPI instead of the future CPI.

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<sup>30</sup>. In their model, expected current price changes are explained solely as a function of past price changes. This specification differs greatly to their structural specifications and the resulting expectations cannot be classified as rational (Pretorius and Van Rensburg 1996: 2).

<sup>31</sup>. There is general consensus among the econometric profession that time series models have superior forecasting performances in the short term.



Similar to the personal tax rate, the indirect tax rate is believed to be known so that no expectations need to be formed.

#### **6.3.5.1.2. *Bank Rate***

Expectations about the Bank rate are modelled for the current period as well as one period ahead. In line with the structural equation, the expectations process is modelled as a function of real credit growth, inflation, the real effective exchange rate and the expected US Libor rate.

The equation of the expectation process governing the Bank rate is of central importance as it represents rational expectations regarding future monetary policy and appropriate tests to confirm rationality are illustrated in Chapter VII.

#### **6.3.5.1.3. *Mortgage Rate***

In line with the structural equations, the expected mortgage rate in the current and future period is modelled as a function of the expected bank rate in the respective periods.

#### **6.3.5.2. *Exogenous Variables***

Variables with respect to which the expectation process is exogenous to the model is the US Dollar Libor rate and the US CPI. Both expectations processes are

specified as a function of moving averages, either with a lagged dependent or autoregressive term.

#### **6.4. CONCLUSION**

Macroeconometric model building is a process of modelling the behaviour of data, taking economic theory and institutional factors into account even though only as a broad guideline. The building of the current model is not different in that regard and is the result of a substantial evaluation of economic theories, data properties as well as statistical and econometric criteria. Particular emphasis in the discussion was placed on highlighting underlying economic theories as well as existing empirical results.

The current model consists of four components, namely demand, supply, a monetary section and a section covering expectation modelling. It is built around the traditional national accounting identities, placing particular emphasis on the demand components of consumption, investment, exports and imports. The supply side of the model consists of the price equations which not only includes the PPI as the basic price equation but also the exchange rate and real wages. The monetary section deals with the money supply, which is primarily determined by credit growth, interest rates and the balance of payments. Also included are long-term interest rates and the reaction function of the SARB, which explains the Bank rate and dictates all other money market interest rates.



Weak rational expectations are formed on the Bank and mortgage rate as well as the consumer price index. It is only the expected US CPI and US Libor rate which are explained exogenously to the model structure. Equations including expectations are real mortgage loans, real net private residential investment, long-term interest rates as well as the exchange rate. In addition, expectations are found in a number of equations that serve themselves as expectation processes.

## **CHAPTER VII: ESTIMATION AND TESTING OF THE MACROECONOMETRIC MODEL**

### **7.1. INTRODUCTION**

The building of an econometric model entails three steps. These are the establishment of the theoretical foundation of the model, the estimation of the actual equations and the evaluation of these equations and the entire model. It is the latter two aspects upon which the focus of this chapter falls. With regard to specification and estimation, increased emphasis in general model building is placed on the concept of cointegration while evaluation of a model is usually performed by in and out of sample simulations.

In Section 7.2, general aspects surrounding estimation and estimator properties are discussed. A particular note is made regarding the concept of cointegration and the problem of multiple cointegration vectors. In Section 7.3, the model is tested by means of in and out of sample simulation and relevant evaluation criteria are highlighted. In Section 7.4, simulated expectations and model forecasts are evaluated to confirm weak RATEX. A detailed description of the model is provided in Appendix I. A description of all data series is provided in Appendix II, while tests for their order of integration are presented in Appendix III. Appendix IV provides a graphical illustration of the dynamic in and out of sample simulation carried out in Section 7.4.



## **7.2. ASPECTS SURROUNDING ESTIMATION**

### **7.2.1. SAMPLE PERIOD AND DATA SOURCE**

The current monetary regime became fully operational only at the beginning of 1984. Consequently, all equations are estimated from the first quarter of 1984 to the fourth quarter of 1995. All primary data has been obtained from the South African Reserve Bank and the Department of Finance. Unless otherwise mentioned, all data is seasonally adjusted at annual rates. Real variables as well as price indices are based on 1990 prices.

### **7.2.2. NON-STATIONARITY AND TESTS FOR COINTEGRATION**

Before tests for cointegration are discussed, a broad outline of the nature of economic time series as well as the concept of cointegration is given.

#### **7.2.2.1. The Non-Stationary Nature of Economic Data**

Most economic variables appear to be non-stationary (Nelson and Plosser: 1982, Enders 1995:181-185). A time series is stationary if its mean and variance are independent of time. Such a series will return to its mean and fluctuations around it will have broadly constant amplitudes. Non-stationary series, on the other hand, will exhibit a time varying mean and an indefinitely large variance, implying that approximations of these statistics cannot be obtained through sample estimation (Cuthbertson et al. 1992:129-130).

Traditionally, non-stationarity was ascribed to a deterministic trend around which the variables are stationary (Hendry 1986:201, McDermott 1990:7). Such a process can be represented by

$$Y_t = G_t + Y_t^s$$

where

$$Y_t^s$$

is the stationary deviation around the long run trend reflected by  $G_t$ .

With such a specification, various detrending techniques can be considered to derive stationarity<sup>1</sup>.

More recently, a large body of evidence has emerged proposing that macroeconomic variables behave as if they have a stochastic trend. Different to the deterministic trend, which implies a fixed increase each period, a stochastic trend cannot be predicted, as it will deviate from its average by a random walk. A stochastic trend can therefore be seen as a random walk process with drift (Stock and Watson 1988:151). A random walk can be represented as

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<sup>1</sup>. One simple way is to regress  $Y_t$  on  $g_t$  and then use the stationary error term,  $Y_t^s$ , as a regressant.



$$Y_t = Y_{t-1} + e_t$$

where  $e_t$  is a white noise process, or with drift<sup>2</sup> as

$$Y_t = B + Y_{t-1} + e_t$$

The economic implications of describing macroeconomic variables as a random walk are quite profound. A random walk can be written as the sum of all error terms with equal weights. This implies that an innovation to the process affects all later values equally so that the process has an indefinitely long memory (Granger 1986:214). For a process like GDP, this would indicate that a shock in the form of a recession could result in real GDP growth to be permanently below the previous trend. The long-term effect is therefore not zero as is implicitly assumed in most theoretical models. They characterise the economy as fluctuating around a determinist trend of potential GDP, assuming any deviations in the form of a recession to be of temporary nature. Taylor (1989:185) argues that the simple statistical finding of stochastic trends in economic series represent a revolution comparable to the impact of the Rational Expectation Hypothesis or the Monetarist's counterrevolution to Keynes' General Theory.

Besides economic implications, non-stationary time series pose particular problems for econometric work, as they can lead to spurious regressions. Such

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<sup>2</sup>. A variable with a stochastic trend can be written as  $Y_t = Y_t^p + Y_t^s$  where  $Y_t^p$  is a random walk with drift and  $Y_t^s$  is stationary.

regressions originate from the attempt to analyse non-stationary time series through ordinary regression techniques. The realisation of the problems associated with such an attempt are not of recent nature as shown by Frisch (as referred to by Brooks and Gibbs 1991:7) who observed that trending variables will tend to be highly intercorrelated even where there is no real economic relationship. Unfortunately, no solution to discriminate spurious from real relationships has emerged for a long time and economists continued to apply standard procedures to economic time series.

Granger and Newbold (1974:111) discovered that a high  $R^2$  and a low Durbin-Watson statistic are typical characteristics of a spurious regression. Their sample experiment provided strong evidence that conventional significant tests are seriously biased towards rejecting the original hypothesis of no significant difference from zero and hence favour the acceptance of spurious relationships even when the series are generated as independent random walks. Granger and Newbold (1974:118) conclude that any regression equation characterised by strong autocorrelated residuals as revealed by a low Durbin-Watson statistic is misspecified, whatever the value of the  $R^2$ .

Influenced by the techniques of Box and Jenkins (1970), the accepted solution to the problem of spurious regression caused by stochastically trending variables has been the repeated differencing to achieve stationarity<sup>3</sup>. However, by analysing

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<sup>3</sup>. Non-stationarity due to a random walk behaviour is attributed to a unit root. The latter refers to the solution of the random walk's characteristic equation (see Pindyck and Rubinfeld (1991:468-470) for a discussion in that regard). By differencing the series once one unit root is eliminated.



differences only, valuable information about possible long run relationships between the levels of variables is lost (Hendry 1986:204). It is this aspect that cointegration addresses.

#### **7.2.2.2. Concept and Implications of Cointegration**

Regression analyses of variables characterised by a stochastic trend can result in misleading inferential conclusions. Cointegration is a special case of integrated time series where this need not be true. The basic rational is that if two or more variables move closely together in the long run (i.e. they have the same stochastic trend), the difference between them is stationary through time even if the series themselves are trending (Harris 1995:22).

Cointegration recognises that even though several series all have unit roots, a combination which does not, can exist. The concept rests therefore on the statistical properties of a linear combination of two or more variables. A formal definition can be given as follows (Robert, Engle and Granger 1987:253):

If the variates of the vector  $X_t$  are all  $I(d)$  and a vector  $\alpha$  (known as the cointegration vector) exists so that  $z_t = \alpha X_t$  is  $I(k)$  where  $k < d$ , then the components of  $X_t$  are cointegrated.

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A time series with one unit root is referred to as integrated of order one ( $I(1)$ ). Similarly, a time series with  $d$  unit roots is referred to as an  $I(d)$  process and has to be difference  $d$  times to derive stationarity.

While the order of integration has to be the same for two variables to be cointegrated, this is not necessary if three or more series are involved (Cuthbertson et al. 1992:133). Given that most economic time series are integrated of order one (primarily ARIMA (p,1,q) processes which is the most general time series representation of an I(1) process (Stock and Watson 1988:151-152)), the error term of the cointegration equation  $z_t = \alpha X_t + e_t$  will be stationary and all the inferential difficulties caused by an I(1) error term of a spurious regression are avoided.

The presence of a stationary error term implies that the stochastically trending variables form a long run equilibrium relationship with any deviations lasting for only a finite time (i.e. the error term is I(0) and not a random walk process). The presence of cointegration is therefore synonymous with a long run relationship between economic variables and a test for cointegration can be used to evaluate the appropriateness of a particular economic theory which proposes a long run equilibrium between particular variables (Mc Dermott 1990:112, Cuthbertson et al. 1992:132).

#### **7.2.2.3. Testing for Non-Stationarity**

Before tests for cointegration can be carried out, it is essential that the order of integration of each series is determined. As mentioned, most economic data series



are expected to be  $I(1)$  processes so that differencing them once will ensure stationarity. Two test procedures were carried out on each time series. These are the Dickey-Fuller or Augmented Dickey-Fuller and the Philips-Perron test (Phillips 1988).

The Dickey-Fuller approach tests the hypothesis for the presence of a unit root in the process

$$Y_t = \delta Y_{t-1} + e_t$$

which is equivalent to the original hypothesis ( $H_0$ )  $\delta = 1$  against the alternative ( $H_a$ )  $\delta \neq 1$ . Equivalently, the model can be written as

$$\Delta Y_t = (\delta - 1)Y_{t-1} + e_t$$

so that the presence of a unit root would imply the absence of  $Y_{t-1}$  as a regressor (Pindyck and Rubinfeld 1991: 459-460). Unfortunately, under the original hypothesis of  $Y_t$  being a random walk, the coefficient  $(\delta - 1)$  cannot be estimated in an unbiased way. The regressor estimate will be biased towards zero which can lead to incorrect rejections of the random walk hypothesis should conventional  $t$ -ratios be employed.

A slight deviation to this test is provided by the augmented Dickey-Fuller test, which makes a parametric adjustment to correct for serial dependency in the residuals (McDermott 1990:9). This adjustment involves the adding of extra lags

of  $\Delta Y_{t-i}$  as regressors to the original Dickey-Fuller regression. For this test as well as the ordinary Dickey-Fuller test, Mackinnon (1988) provides a list of critical values for a number of cases (restrictions) and degrees of freedom.

The Phillips-Perron test is a similar approach to the Dickey-Fuller test. However, no lagged difference terms are included but the  $t$  statistic is corrected for serial correlation after the application of OLS. For a discussion and comparison of the Dickey-Fuller, Augmented Dickey-Fuller and Phillips-Perron tests, see Holden and Perman (1994:56-71) or Banerjee et al. (1993:206-214, 230-235).

#### **7.2.2.4. Tests for Cointegration**

In the current study, two types of cointegration tests were carried out. The test for the stationarity of the error term was carried out with the help of the augmented Dickey-Fuller and Phillips-Perron tests. These procedures were applied to the error term of the cointegration equation. However, Cuthbertson et al. (1992:136) points out that there are additional complications when these tests are assigned to the residuals. Given that OLS minimises the sum of squared residuals, the error terms will have the smallest possible variance even if cointegration does not prevail. Should a unit root actually be present, the OLS estimators of the cointegration vector will be biased, generating residuals that will favour a rejection of  $H_0$  too often.



In addition to the residual based tests, the Johansen test was applied to test for the number of significant cointegration relationships among a given set of variables. This is essential as the estimation of the long relationship through OLS assumes that there is only one cointegration vector. A lagged dependent variable was not included in this test even though it was included in the specified equation. Lagged dependent variables serve the purpose of catching the dynamics or adjustment of a variable. The equilibrium relationship governing the variables is given by a representation excluding the lagged dependent variable. Given that cointegration refers to the equilibrium relationship among variables, the lagged dependent variable needs to be excluded. Hall (1996) refers in that regard to the notion of balance. The properties of the left side of an equation have to equal those on the right. This means that the explanatory variables' non-stationarity and not the non-stationarity of the lagged dependent variable have to cancel out the non-stationarity of the dependent variable<sup>4</sup>.

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<sup>4</sup>. Consumption functions provide an example. Models explaining consumption behaviour are usually specified with a lagged dependent variable on grounds of habit or because of the result of a transformation. However, in his fundamental law, Keynes (1941:96) states that '*the fundamental psychological law, upon which we are entitled to depend with great confidence...is that men are disposed, as a rule and on average, to increase their consumption as their income increases...*'. Thus, at equilibrium, there is a relationship between consumption and income. There could be an additional relationship with interest rates and wealth or expected income but not with lagged consumption. Indeed, an integrated variable of order one cannot have a stable equilibrium with its own lagged value as such a specification defines a random walk.

The Johansen technique starts with an unrestricted VAR specification<sup>5</sup>:

$$z_t = A_1 z_{t-1} + A_2 z_{t-2} + \dots A_k z_{t-k}$$

where  $z_t$  is a vector of  $n$  endogenous variables.

This equation is then reformulated into a vector error correction model (this is known as a cointegrating transformation):

$$d(z_t) = B_1 d(z_{t-1}) + B_2 d(z_{t-2}) \dots C_k z_{t-k} + u_t$$

where  $d(z_t)$  refers to first differences of  $z$ .

Since the error term is stationary, this equation must balance meaning that the order of integration must be the same for both sides (Darnell 1994:203). Assuming that all variables are  $I(1)$ , all variables are  $I(0)$  once first differences are taken. For the assumption of a stationary error term, it is therefore necessary that  $C_k z_{t-k}$  is also stationary. This term represents a linear combination of the  $n$  variables. If  $C$  is of full rank, then  $C_k z_{t-k}$  is a vector of  $n$  linear combinations of the  $n$  variables of  $z$ , which implies that there are no cointegration relationships (Darnell 1994:204). Thus, evaluating the rank of  $C$  gives an indication of the cointegration relationships.

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<sup>5</sup>. Different to residual based tests, the Johansen procedure does not impose any strong a priori restrictions such as a particular relationship (Harris 1995:77). Given that it is based on VAR, the inclusion of a lagged dependent variable would lead to a singular matrix and would be



If one cointegration relationship prevails,  $C$  cannot be of full rank as two of its vectors are linearly dependent. Therefore, evaluating the rank of matrix  $C$  gives an indication of the number of cointegrating relationships. The number is equal to  $n - \text{rank}(C)$ . Testing for the rank of  $C$  involves the evaluation of the eigenvalues (or characteristic roots) of that matrix. It is this evaluation upon which the Johansen procedure is based. It involves the estimation of the rank of  $C$  by examining the characteristic roots. (The rank is equal to the number of non zero roots). The test proceeds by estimating the eigenvalues (which are all between zero and one) and then testing how many of them are zero. For a detailed discussion of the Johansen test, see Darnell (1994:203-209) or Harris (1996:77-79). For a step by step application of the Johansen technique, see Dickey et al. (1994:24-26,43-44) or Harris (1996:76-95). For an example of its application and explanation, see Cuthbertson et al. (1992:143-148) or Banerjee et al. (1993:292-293).

### **7.2.3. ESTIMATION METHOD**

#### **7.2.3.1. Granger's Representation Theorem and Error Correction Modelling**

As previously pointed out, differencing time series results in the loss of valuable long run information. An econometric model estimated by first differences can only be used for short-term policy evaluation, as all information regarding a potential long run relationship between the levels of the variables is lost. An error

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meaningless.

correction model, on the other hand, introduces a stationary variable reflecting levels among other differenced time series to incorporate such a long run trend. Cointegration is central to this approach as it ensures the stationarity of this variable.

An error correction model incorporates long run equilibrium relationships with the type of short-term dynamic model favoured by time series econometricians. The equilibrium relationship is allowed to enter the model but is not forced to do so. The Error Correcting Term ensures, however, that the disequilibrium of one period is corrected in the next. In an Error Correction Model, deviations from the long run equilibrium condition feed back into the short run dynamics so that the long run relationship is maintained.

The extension of the short run model is achieved by introducing an Error Correction Term as a regressor into the specified model. This Error Correction Term is the stationary error term as it results from the estimation of a long run relationship of cointegrated time series. As previously mentioned, if a set of variables is cointegrated of order one, then the residual is stationary and represents the error correction term. The latter is the distance the system is away from equilibrium in period  $t$  and will, given cointegration and therefore joint movement of variables, influence the change of the dependent variable in the future. Accordingly, the Error Correction Model can be represented as follows:



$$Y_t - \alpha X = \varepsilon_t \quad (\text{Long run cointegration equation})$$

$$\Delta Y_t = \beta_1 \Delta X + \beta_2 \varepsilon_{t-1} + \beta_3 \Delta T + v_t \quad (\text{Short run Error Correction Model})$$

where

$Y$  and  $X$  are cointegrating variables,  $\varepsilon_{t-1}$  is a stationary error term<sup>6</sup>,  $v_t$  is the error term of the short run specification and  $T$  represents additional variables included in the short-run specification (e.g. lagged dependent).

This representation is known as Granger's Representation Theorem which states that if a set of  $I(1)$  variables are cointegrated then there exists an error correction model, the error correction term being formed by using the error term of the cointegration equation (Darnell 1994: 114 -117, Banerjee et al. (1993: 146-153).

### 7.2.3.2. Estimation of Model

Once the presence of cointegration is confirmed, a long run equation has been estimated for each specification followed by an Error Correction or short run model. Due to its simplicity, the Two Step Estimation Approach of Granger has been applied. The first step involves the estimation of the cointegration vector

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<sup>6</sup>. For all variables, first differences are defined as the quarter-on-quarter change in the series. For a quarterly model, an alternative could have been the change over 4 quarters, modelling the yearly change in the data. Most quarterly models, such as the one of the Bank of England (1999), have focused on quarterly rather than yearly change. An exemption is the model of the Bundesbank (1996).

based on a pre-specified long run relationship (i.e. the long run equation). The second step involves the estimation of the Error Correction Model based on the estimated cointegration residuals (Darnell 1994: 114 - 117). For both steps, OLS has been used as an estimation technique. In the case of an expectation variable, IV estimation was used as outlined in Chapter III. The computer programme used for all econometric work is *Econometric Views Version 2.0*.

Gonzalo, as referred to by Banerjee et al. (1993: 285) has compared the performance of the Engle Granger Two Step approach with Maximum Likelihood estimation. One of the conclusions was that Maximum Likelihood estimators appear to do better at larger sample sizes. Phillips (as referred to by Brooks and Gibbs 1991: 8), on the other hand, suggests the adding of first differences of the explanatory variables into the long-run cointegration regression to correct for omitted dynamics, which are forced into the error term. Their coefficients are unimportant as their inclusion is solely aimed at reducing the finite sample bias. This approach has not been followed in the current study.

Granger's representation theory was also applied to the expectations equations. Therefore, the short-run equations include the expectations error made in the previous period and the individual is not indifferent to these errors.

For one period ahead expectations, the error correction term would imply an expected error rather than the actual difference between expectations and outcome. To ensure that the error term can be interpreted as a learning process, the same error correction term was used for one period ahead expectations as for current



expectations. Thus, a change in period  $t$  of one period ahead expectations depends partly on the actual forecast error made in period  $t-1$ .

During simulations, the error correction term is not derived from a long run expectations equation but refers to the difference between the short run expectation forecast and the structural model's short run forecasts. Given that expectations and actual model solutions cointegrate, the error term will be stationary<sup>7</sup>.

#### **7.2.4. ESTIMATOR PROPERTIES**

In the case of simultaneous equations, the application of OLS has been severely criticised by the Cowles Commission on grounds of inconsistent estimates. However, Epstein (as referred to by McDermott 1990:13) maintains that OLS has proven to be much more robust than the Cowles Commission expected and that it has rarely been shown to be inferior to other estimation techniques when used with macroeconomic data. Furthermore, since the 1970's, the emphasis was on estimation, more recent focus has been on testing and diagnostic evaluation (Pauly 1996).

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<sup>7</sup>. The stationarity of the error term is crucial to ensure weak RATEX as a significant ECT term suggests that expectation errors influence future expectations and that not all information has been taken into account. Given, however, stationarity, no systematic forecast errors are allowed in the long run. Applying an Error-Correction Model and defining the ECT term in the above fashion provides an alternative framework for testing for rational expectations (see Bakhshi and Yates (1998) for an empirical application). Lopes (1998:269-271) uses Granger's Representation theory to test for RATEX and argues that any significant ECT term would imply a learning

Cointegrated processes have different properties to stationary time series. While the cointegration error is finite with second variance, other linear combinations are not. According to Stock (1987:1036), this suggests that OLS should produce relatively precise estimators of the cointegration vector but also that standard asymptotic results will not apply.

#### **7.2.4.1. Super Consistency**

A rather favourable characteristic is what has become known as super consistency. The OLS estimators of cointegrated time series have a non-normal limiting distribution. Nevertheless, these estimators converge to this limiting distribution at a faster rate than ordinary OLS estimators do to their normal distribution. Stock (1987:1037,1039,1050) has shown that if the cointegration vector is identified through normalisation, the estimators of the cointegration vector converge in probability to their true value as sample size  $T$  tends to infinity while OLS estimators of non-cointegrating relationships converge only at a rate of  $T^{1/2}$ .

Super consistency does not require the assumption of the regressors and the error terms being uncorrelated so that this result even holds for dynamic model specifications. It is the existence of highly collinear trending variables that produces super consistency. However, what is essential is that all variables in the static cointegration regression are  $I(1)$  and that no subset of the specified long-run relationship is cointegrated (Hendry 1986:208).



#### 7.2.4.2. Finite Sample Bias

Although the estimators of the cointegration vector converge in probability at a fast rate to the true cointegration vector, these estimators appear to be biased for finite samples<sup>8</sup>. Stock (1987:1050) argues that this bias can be quite substantial, especially for small samples and claims that the cause for this unfortunate estimator characteristic rests on a distribution which is generally skew with non-zero mean after standardisation.

Banerjee (as referred to by Hendry 1986:206)) shows that for simple data processes, this bias is strongly positively correlated with the  $(1-R^2)$  from the cointegration regression. Cointegration regressions with small  $R^2$  should be treated with caution. Brooks and Gibbs (1991:8) suggest that the choice of the normalisation variable (dependent variable) should be made subject to the highest possible  $R^2$ <sup>9</sup>. However, as Banerjee et al. (1993:220) point out, a large  $R^2$  is not a sufficient requirement for low biasness as the additional inclusion of regressors into the cointegration equation will automatically increase  $R^2$ . With the help of Monte Carlo studies, Banerjee et al. (1993:215-220) give some indication of how the bias declines with increased sample size.

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<sup>8</sup>. While a consistent estimator will approximate the true value as the sample information increases, a biased estimator will on average (several estimations with constant sample size) not equal the true parameter (Griffiths, Hill and Judge 1993: 81-85).

<sup>9</sup>. The econometric model of the Reserve Bank of New Zealand was estimated in such a fashion

### 7.2.5. THE PROBLEM OF UNIQUENESS

Despite its simplicity and popularity, estimating cointegration equations with OLS has a rather stingy disadvantage. As soon as there are more than two cointegrated series, the door is opened for a large number of possible interrelationships and models to prevail. This implies that the cointegration vector is no longer unique, allowing several equilibrium relationships to link the cointegrated series. This property strongly narrows the application of this approach to help clarifying controversies in macroeconomics and consequently policy evaluation, as there might be (for example) both, a Monetarist and a Keynesian cointegration vector (McDermott 1990:15, Granger 1986:220). The number of possible cointegration vectors defines the cointegration rank, which is smaller or equal to  $N-1$ , where  $N$ , stands for the number of cointegration variables in question. A solution to the identification of the uniqueness problem is provided by the previously mentioned Johansen technique which estimate all possible cointegration vectors and derives appropriate tests for their statistical significance.

If cointegration is found among the variables in an equation based on OLS, there is no guarantee that the estimation is a reflection of a unique cointegration vector. Indeed, the OLS estimated relationship could be a linear combination of the actual cointegration relationships (Cuthbertson et al. 1992:144). In this case, the actual relationships governing the variables have not been identified but rather an incorrect relationship is portrayed. It is therefore incorrect to say that even though

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(see Brooks and Gibbs 1991).



there are numerous cointegration relationships, OLS will project at least one of them.

#### **7.2.6. INTERPRETATION OF MULTIPLE COINTEGRATION VECTORS**

The interpretation of multiple cointegration vectors requires special consideration. *'Confusion remains over what information the estimated cointegration vectors really convey. Only where there is a single cointegration vector is the interpretation unambiguous; in this case the cointegration vector is equivalent to the coefficients of a cointegration regression, and hence provides an estimator of the coefficients of the  $I(1)$  variables in a long run model'* (Wickens 1993:1). Thus, the coefficients derived from normalised cointegration vectors cannot be interpreted in a structural way. These coefficients describe the relationships that hold the variables together or in equilibrium but say nothing about the structural relationships underlying the variables. In particular, there will not be a unique relation between cointegration vectors and economically meaningful target relations. As Hall and Wickens (1993) point out *'except in the special case where  $r=1$  (one cointegration vector) the estimated cointegration vectors may be any linear combination of the underlying target relations'*. All that can be said is that the series do cointegrate but no interpretation regarding the equilibrium relationship governing the variables can be made by simply looking at the multiple cointegration vectors.

In spite of the interpretation problem, the long run relationship among cointegrating variables is uniquely defined, even if there are several cointegration vectors. Darnell (1994:208) gives the following example to clarify the issue.' *A linear relationship between three variables defines a three-dimensional plane, and the existence of two distinct cointegration vectors defines two distinct but intersecting planes. The intersection of two planes defines a line in three-dimensional space, which defines the unique long run equilibrium path. It is not that there are two equilibrium in the long run but rather that there is a unique path defined by the conjunction of three cointegrated relationships between the three pairs of variables.*' However, only through identifying restrictions on the cointegration vectors can the target relationship be derived. There are tests available for confirming the significance of such restrictions (see Cuthbertson et al. (1992:148-149), Banerjee et al. (1993:276-278) or Harris (1995:104-117)).

Dickey, Jansen and Thornton (1994:22) points out that '*Cointegration vectors can be thought of as representing constraints that an economic system imposes on the movements of the variables in the system in the long run*'. Accordingly, finding more than one cointegration vector implies that the system of variables is so much more stable (Dickey, Jansen and Thornton 1994:23).

Given the problem of interpreting multiple cointegration vectors and relating them to structural coefficients, Wickens (1993:19) concludes that '*cointegration analyses has only limited practical usefulness confined largely to situations where the variables correspond to a small, well defined subset, a single structural equation being an example*'. Cointegration tests carried out in this study must be



seen in this context in that they are used to identify long run relationships among subsets of variables (single equations) that have been separated and specified on a priori economic theory<sup>10</sup>. However, even with such subsets the possibility of multiple cointegration vectors cannot totally be excluded. There are several equations in the model for which the hypothesis of more than one cointegration rank cannot be rejected. These equations will be pointed out and special attention needs to be given regarding their interpretation.

According to Darnell (1994:207-208), the reason for multiple cointegration vectors is that a subset of the cointegration variables already cointegrates. Thus, more than one cointegration vector implies that there are long-run relationships amongst subsets of variables and not just among the complete set of variables. One of the normalised cointegration vectors would then include zero terms, an assumption that would have to be tested (see Holden and Perman 1994:87) for an example). This could be one of the explanations for the multiple cointegration vectors found in some of the single equations of the current study as a subset of some of the explanatory variables are modelled separately in a further cointegration equation. Because of the simultaneity and limited degrees of freedom, it is not possible to jointly test for all cointegration vectors found among variables related on a priori economic knowledge.

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<sup>10</sup>. Applying the Johansen technique to the model as a whole would mean that all endogenous variables would have to be included in the vector  $z$ . This test would then indicate the total number of cointegrating relationships. The structural equations could then be derived from testing imposed restrictions on all these relationships. However, what makes this approach practically unfeasible is the small number of data points available relative to the requirements of

### 7.2.7. DETAILED MODEL DESCRIPTION

As discussed in detail in the previous chapter, the model can be subdivided into the conventional aggregate demand components, supply components such as wages and other prices, a monetary component that covers the interest rates and the money supply as well as a Section on expectations processes. Appendix I provides a detailed representation of all estimated equations and identities of the model. Statistical and econometric evaluation criteria for each estimated equation, including cointegration tests, are also provided.

Each equation underwent a number of stability tests. These include the evaluation of the recursive residuals and coefficients as well as CUSUM and CUSUM of squares tests to ensure coefficient and function stability before a final specification was chosen (Galpin and Hawkins 1984). As mentioned, the 1980's represent a turbulent time period and as a result, the data reflects noise or movement. Dummy variables were used to address this problem. They were included on an a priori specification basis only if clearly identifiable events could be linked to the behaviour of the data. In addition, information obtained from stability tests was used to identify influential data points, outliers and structural breaks.

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this approach.



### **7.3. EVALUATION OF THE MODEL - IN AND OUT OF SAMPLE SIMULATION**

According to Pauly (1996), a good model is one that is theoretically meaningful, statistically acceptable and data representative. Similarly, Pesaran and Smith (1985: 125-133) identify three criteria for model evaluation. The aspect of relevance with regard to the purpose of the model has played a central role in the model's construction with regard to disaggregation and the inclusion of equations. The second criterion of data representation is a standard aspect in model specification and evaluation. This criterion refers to the above-discussed aspects of model selection on grounds of hypothesis testing,  $R^2$  and other statistics and diagnostics. The final criterion of consistency refers to internal consistency of the model so that no contradictory equations prevail as well as consistency with regard to economic theory. Single equation evaluation ensures this criteria. However, it is not seldom that economic theory provides little guidelines with regard to detailed model specification and in as well as out of sample simulation exercises can be more insightful, particularly with regard to dynamic stability.

Dynamic in sample simulations were carried out for the period 1990Q1 - 1995Q4 while out of sample simulations were carried for the period 1996Q1- 1997Q1. Appendix VI provides a graphical representation of a dynamic simulation for the entire period 1990Q1 – 1997Q1. In addition, the root mean squared percentage

error (RMSPE) was used as an evaluation criterion<sup>11</sup>. The following results can be reported:

**Table 7.1: Root mean square percentage error for dynamic simulations**

<b>VARIABLE</b>	<b>In sample 1990Q1 – 1995Q4</b>	<b>Out of sample 1996Q1 – 1997Q1</b>	<b>Total period 1990Q1 – 1997Q1</b>
Private consumption expenditure: Real	3.33	0.62	3.12
Gross domestic fixed investment: Real	5.10	4.71	4.70
Merchandise imports: Real	7.16	4.48	6.59
Merchandise exports: Real	3.97	3.75	3.92
Employment in the non-agricultural private sector	1.62	2.50	1.73
Wage rate: Real	2.76	2.21	2.69
Money supply: M3	1.43	3.66	1.82
Yield on long term government stock	6.88	9.15	8.56
Bank rate	6.31	4.68	6.29
Long term capital movements of the non-monetary private sector	30.87	15.14	28.36
Personal direct taxes	2.66	2.56	2.99
Corporate direct taxes	5.48	5.11	5.70
Indirect taxes of general government	3.70	1.85	3.67
Interest on public debt	4.00	1.52	3.90
Rand/US\$ spot exchange rate	4.63	12.62	6.70
Import prices	3.03	4.31	3.05
Non-gold export prices	3.62	3.22	3.38
Consumer price index	2.39	0.58	2.44

The statistics in Table 7.1 and the graphs in Appendix IV confirm that the model is an adequate representation of the economy.

<sup>11</sup> See Pindyck and Rubinfeld (1991: 336 - 342) for a definition and discussion of this and other evaluation criteria for simulation models.



#### 7.4. TESTING FOR MODEL CONSISTENT EXPECTATIONS

To confirm model consistent expectations, the simulated expectations need to be compared with the corresponding simulation results of the structural equations. As pointed out, the least requirement is that of cointegration between expectation and model results<sup>12</sup>. In addition to that, the root mean square percentage error between the solutions of the endogenous variables and the expectation variables are computed. A more strict test for weak RATEX is that the expected expectation error is zero and not correlated with past errors thereby confirming that no systematic expectation errors are made. This requirement is tested by evaluating the significance of the coefficients in the following regression<sup>13</sup>:

$$e_t = \alpha_0 + \alpha_1 * e_{t-1} + \epsilon_t \quad (1)$$

where

$e_t$  is the difference between the forecast of the expectations process and the respective endogenous variable.

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<sup>12</sup> . The existence of a cointegration relationship is taken to be evidence for the rationality of expectations in Liu and Maddala (1992).

<sup>13</sup> . This test is based on Maddala (1992: 434-436). For an application as well as extension of this test, see Bakhshi and Yates (1998) or Kim (1997). Kim (1997: 1011, 1017-1020), who defines weak RATEX as forecasts based on all available and relevant information, applies a more general MA structure to the forecast error. Harvey (1996), following Davidson's critique as elaborated in Chapter II, tests for the rational expectations hypothesis in survey data within a Post-Keynesian framework and refutes RATEX on the basis that expectations are causal.

Model consistent expectations imply that both coefficients should be insignificantly different from zero and  $\epsilon_t$  is a white noise process. Should the coefficients be significant, the economic agent has to re-evaluate the expectation process as information has been neglected on a persistent basis. For one period ahead expectations, equation (1) needs to be altered. This is given by the fact that the expectation error made for period  $t+1$  in period  $t$  cannot be compared with the expectation error in period  $t$  as the latter is also not known to the individual. As a result, equation (1) needs to be modified with regard to two aspects:

1. The individual compares the one period ahead expectations for period  $t$  made in period  $t-1$  with the current expectations made for period  $t$ . Current expectations serve as revised forecasts for one period ahead expectations so that the discrepancy between the two can serve a proxy for the one period ahead forecasting error.
2. Given that the expectation error for period  $t+1$  partly depends on the expectations error for period  $t$ , a revised one period ahead forecast can only be carried out once the actual forecasting error is known. This implies an evaluation of the one period ahead expectation error made in period  $t-1$  rather than in period  $t$ .

Combining these two issues results in the following specification:

$$v_{t+1} = \alpha_0 + \alpha_1 v_{t-1} + \alpha_2 u_t + \epsilon_t \quad (2)$$



where

$v$  refers to the one period ahead expectation error and  $u$  refers to the current expectation subtracted from the one period ahead expectation for the same period.

If the individual utilises all the information at his disposal, then all of the coefficients of equation (2) should be insignificantly different from zero.

In summary, the following statistical results can be reported:

**Table 7.2: Tests for model consistent expectations based on dynamic in and out of sample simulation 1990Q1 - 1997Q1**

<b>Expectations variable</b>	<b>Cointegration test (1% : 16.31; 5% 12.53)</b>	<b>T values (intercept and coefficients)</b>	<b>R<sup>2</sup> and D.W statistic</b>
<b>E(Bank rate)<sub>t</sub></b>	<b>18.1</b>	<b>-0.06;1.56</b>	<b>0.08;1.94</b>
<b>E(Bank rate)<sub>t+1</sub></b>	<b>51.9</b>	<b>-0.74;1.42;1.76</b>	<b>0.25; 1.80</b>
<b>E(Mortgage rate)<sub>t</sub></b>	<b>21.0</b>	<b>-1.07;1.65</b>	<b>0.09;1.91</b>
<b>E(Mortgage rate)<sub>t+1</sub></b>	<b>26.0</b>	<b>-0.2;-1.60;-2.03</b>	<b>0.33;1.81</b>
<b>E(CPI)<sub>t</sub></b>	<b>17.7</b>	<b>0.20;-1.28</b>	<b>0.06;1.96</b>
<b>E(CPI)<sub>t+1</sub></b>	<b>12.8</b>	<b>-0.85;1.01;-0.01</b>	<b>0.04;1.56</b>

All test results and equation statistics refer to model solutions of the base run

simulation. Thus, the model's solution of an endogenous variable and its solution of the corresponding expectations process are evaluated. The above test applies therefore to dynamic model consistent expectations.

The cointegration tests confirm that all dynamically simulated expectations and model solutions cointegrate at the 5 per cent critical level. Weak RATEX is therefore confirmed for all expectations. For the expectation processes of the current period rational expectations is confirmed as all t tests indicate insignificant estimates at the 10 per cent level. In addition, the information provided by lagged error terms, as reflected by the  $R^2$  statistic, is rather low. The low RMSPE in Table 7.3. confirm this conclusion from a dynamic perspective.

**Table 7.3: Root mean square percentage error for dynamically simulated expectations and model solutions**

EXPECTATIONS VARIABLE	RMSPE
$E(\text{Bank rate})_t$	0.41
$E(\text{Bank rate})_{t+1}$	3.20
$E(\text{Mortgage rate})_t$	0.35
$E(\text{Mortgage rate})_{t+1}$	2.89
$E(\text{CPI})_t$	0.44
$E(\text{CPI})_{t+1}$	0.90

In the case of one period ahead expectations, some of the t values do suggest significance at the 10 per cent and possibly 5 per cent critical level. However, the share of the expectations error explained by previous errors is again rather limited



(25 and 33 per cent). With a D.W statistic of around 2 and thus no further information other than the one found in previous expectation errors, a future expectations error cannot be reduced by more than the limited information content of previous errors. Also, the low RMSPE show that the additional utilisation of information is unwarranted on grounds of forecasting accuracy. This aspect touches on the previous conclusion that the additional inclusion of variables into an expectation process might not be rational if cointegration prevails and the expectations are fairly accurate. The RMSPE confirm the limited information content of previous expectation errors from a dynamic perspective, which confirms weak RATEX.

## **7.5. CONCLUSION**

Increased attention in model building over recent years has been given to the non-stationary nature of economic time series. This non-stationarity can primarily be attributed to a stochastic trend, leading to most economic data being classified as  $I(1)$  processes. This characteristic necessitates the modelling of economic relationships in first differences to avoid the by now well-illustrated spurious regression problem.

Modelling economic relationships in first differences ignores the long run dynamics. The concept of cointegration and the resulting application of an Error Correction Model overcome this problem. A cointegrating relationship provides a stationary error term, allowing the inclusion of this error term in level form in an equation specified as first differences. While the cointegrating long run

relationship can be directly incorporated into the ECM specification, the two equations are stated as separately in the current study.

If a cointegrating relationship includes more than two variables, the possibility is given for more than one cointegration vector to prevail. The Johansen test procedure applied to each single equation of the model does confirm that this is indeed the case for a number of equations or subsets of variables. While this questions the applicability of Granger's Representation Theorem, a long and short run equation was nevertheless specified for the respective subsets of variables on the basis of a priori economic theory.

Numerous single equation tests were carried out as well as an in and out of sample simulation to test for equations and model characteristics. These test results as well as a full description of the model are provided in the appendices. From these measures, the model is believed to be an adequate reflection of the economic relationships governing South Africa.

Tests for weak RATEX include tests for cointegration as well as the significance of previous error terms in explaining present expectation errors. Significant cointegrating relationships between expectations and model solutions can be confirmed for all expectations of the model. The study also shows that although not all information is necessarily taken into account, the potential gain of fully incorporating expectation errors of the past is rather limited. All endogenous expectations can therefore be classified as weak RATEX.



**APPENDIX I**  
**DETAILED DESCRIPTION OF THE MODEL**

**EXPENDITURE COMPONENTS**

*Private consumption expenditure*

1. Durable consumption: Real

◆ *Long-run equation*

$$R6050D = \beta_0 + \beta_1 RDWB + \beta_2 (R1374N/CP) + \beta_3 D84Q12 + \sum_{i=4}^6 \beta_i RINT10Q_{(1-i)}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<i>Coefficient value</i>	-13585	0.188	0.048	5500	-23.87	-31.83	-23.87
<i>T value</i>	-6.76	9.30	3.53	13.65	-3.04	-3.04	-3.04

*R2*            *0.91*  
*D.W.*        *1.63*  
*Johansen*   *82.06 (1%:54.46)*  
                  *41.50 (1%:35.65)*  
*Tests confirm 2 significant*  
*cointegration vectors*

◆ *Short-run equation*

$$D(R6050D) = \beta_1 D(RDWB) + \beta_2 D((R1374N/CP)) + \beta_3 D(D84Q12) + \beta_4 D(YPHH) + \beta_5 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<i>Coefficient value</i>	0.106	0.042	6206	0.041	-0.71
<i>T value</i>	2.87	1.62	12.41	1.95	-4.96

*R2*                    *0.85*  
*D.W.*                *1.73*

2.      Semi-durable consumption: Real

◆ *Long run equation*

$$R6055D = \beta_0 + \beta_1 RDWB + \beta_2 E(RILQ22_{(+1)}) + \beta_3 (R1374N/CP) + \beta_4 YPHH + \beta_5 DUM93Q2 + \beta_6 DUM91Q1$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<i>Coefficient value</i>	-22415	0.236	-443.5	0.161	0.122	994.6	-1537
<i>T value</i>	-9.52	9.88	-7.11	7.90	7.06	4.33	-3.52

*R2*                    *0.98*  
*D.W.*                *1.62*  
*Johansen*        *75.49 (5%:68.52)*  
*Test confirms 1 significant*  
*cointegration vector*

◆ *Short run equation*

$$D(R6055D) = \beta_1 D(RDWB) + \beta_2 D((R1374N/CP)) + \beta_3 D(YPHH) + \beta_4 D(DUM84Q2) + \beta_5 D(DUM91Q1) + \beta_6 ECT_{(-1)} + \beta_7 D(R6055D_{(-1)})$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<i>Coefficient value</i>	0.087	0.054	0.047	739.6	-1444	-0.38	0.252
<i>T value</i>	4.44	4.27	4.36	4.24	-8.45	-3.79	3.03

*R2*                    *0.75*  
*D.W.*                *1.32*



3. Non-durable consumption: Real

◆ Long run equation

$$R6061D = \beta_1 RDWB_{(-1)} + \beta_2 (R1374N/CP) + \beta_3 R6061D_{(-1)} + \sum_{i=4}^6 \beta_i RINT10Q_{(4-i)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<b>Coefficient value</b>	0.125	0.143	0.585	-109.2	-145.5	-109.2
<b>T value</b>	4.70	5.76	9.06	7.20	7.20	7.20

**R2** 0.97  
**D.W.** 1.63  
**Johansen** 70.17 (1%:54.46)  
**Test confirms 1 significant cointegration vector**

◆ Short run equation

$$D(R6061D) = \beta_1 D(RDWB_{(-1)}) + \beta_2 D(R1374N/CP) + \beta_3 D(R6061D_{(-1)}) + \beta_4 DUM83Q4Q1 + \sum_{i=5}^7 \beta_i D(RINT10Q_{(5-i)}) + \beta_8 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	0.120	0.146	0.489	-1696	-142.4	-189.9	-142.4	-0.74
<b>T value</b>	2.89	4.22	3.63	-2.81	-4.73	-4.73	-4.73	-3.73

**R2** 0.64  
**D.W.** 1.68

4. Services: Real

♦ Long run equation

$$R6068D = \beta_1 RDISA + \beta_2 (R1374N_{(-2)} / CP_{(-2)}) + \beta_3 TREND_{(1984)} + \beta_4 DUM91Q1 + \sum_{i=5}^7 \beta_i RINT10Q_{(5-i)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	0.158	0.147	97.49	1665	-98.91	-131.9	-98.91
<b>T value</b>	12.97	10.14	9.29	2.74	-8.63	-8.63	-8.63

**R2**                    **0.98**  
**D.W.**                **1.46**  
**Johansen**        **53.56 (5%:47.21)**  
**Test confirms 1 significant**  
**cointegration vector**

♦ Short run equation

$$D(R6068D) = \beta_0 + \beta_1 D(RDISA) + \beta_2 D(DUM91Q1) + \beta_3 ECT_{(-1)}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$
<b>Coefficient value</b>	212.3	0.06	993.4	-0.38
<b>T value</b>	3.16	3.03	3.14	-3.04

**R2**                    **0.35**  
**D.W.**                **2.06**

5. Total private consumption expenditure: Real

$$R6008D = R6050D + R6055D + R6061D + R6068D + ZC$$



6. Total private consumption expenditure: Nominal

$$R6008L = R6008D * (CP / 100)$$

**Gross domestic fixed investment**

7. Private non-residential: Real

◆ Long run equation

$$IP = \beta_1 IP_{(-1)} + \sum_{i=2}^4 \beta_i RB2003M_{(-i)} + \sum_{i=5}^7 \beta_i R6006D_{(5-i)} + \beta_8 DUM86Q1 + \beta_9 DUM94Q1$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
Coefficient value	0.744	-129.3	-172.4	-129.3	0.015	0.02	0.015	-4288
T value	13.33	-3.37	-3.37	-3.37	4.78	4.78	4.78	-4.16

	$\beta_9$
Coefficient value	293.4
T value	3.27

R2                    0.94  
D.W.                1.92  
Johansen          36.94 (5%:34.91)  
Test confirms 1 significant  
cointegration vector

◆ Short run equation

$$D(IP) = \sum_{i=1}^3 \beta_i D(R6006D_{(1-i)}) + \beta_4 D(IP_{(-1)}) + \beta_5 D(DUM86Q1) + \beta_6 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<b>Coefficient value</b>	0.044	0.060	0.044	0.677	-4157	-0.99
<b>T value</b>	1.82	1.82	1.82	4.26	-5.59	-4.56

**R2**                    **0.58**

**D.W.**                **1.8**

## 8. Private residential: Real

### ◆ Long run equation

$$\begin{aligned} \text{LOG}(\text{IPR}) = & \beta_1 \text{LOG}(E(\text{RILQ22}_{(+1)})) + \beta_2 \text{LOG}(\text{RDISA}) + \beta_3 \text{LOG}(\text{INP} / \text{CP}) + \beta_4 \text{TREND}_{(1984)} \\ & + \beta_5 \text{LOG}(\text{IPR}_{(-1)}) + \beta_6 \text{DUM88Q1} + \beta_7 \text{D94Q1} \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	-0.232	0.332	-0.268	-0.007	0.646	-0.137	0.008
<b>T value</b>	-4.29	3.40	-2.03	2.99	5.74	-3.69	1.73

**R2**                    **0.95**

**D.W.**                **1.69**

**Johansen**        **76.01 (1%:70.05)**

**Test confirms 1 significant**  
**cointegration vector**

### ◆ Short run equation

$$\text{DLOG}(\text{IPR}) = \beta_1 \text{DLOG}(\text{RDISA}) + \beta_2 \text{DLOG}(\text{IPR}_{(-1)}) + \beta_3 \text{D}(\text{DUM88Q1}) + \beta_4 \text{ECT}_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$
<b>Coefficient value</b>	0.575	0.943	-0.157	-1.28
<b>T value</b>	3.04	6.04	-6.22	-6.20

**R2**                    **0.58**

**D.W.**                **1.82**



9. Change in inventory: Real

◆ Long run equation

$$R6010D = \beta_0 + \sum_{i=1}^3 \beta_i RINT10Q_{(1-i)} + \sum_{j=4}^6 \beta_j (GDD_{(4-j)} / GDD_{(-j)}) + \beta_7 DUM93$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	-73810	-123.2	-164.3	-123.2	23669	31559	23669	3306
<b>T value</b>	-4.40	-2.54	-2.54	-2.54	4.87	4.87	4.87	2.76

**R2** 0.55  
**D.W.** 2.26  
**Johansen** 45.43 (1%:41.07)  
**Test confirms 1 significant cointegration vector**

◆ Short run equation

$$D(R6010D) = \sum_{j=1}^3 \beta_j D(GDD_{(1-j)} / GDD_{(-j-3)}) + \beta_4 D(DUM85Q4) + \beta_5 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<b>Coefficient value</b>	22349	29798	22349	-7026	-1.07
<b>T value</b>	1.73	1.73	1.73	-3.26	-7.81

**R2** 0.69  
**D.W.** 1.72

10. Gross domestic fixed investment: Real

$$R6009D = IP + IPR + RB6100D + RB6106D + ZI$$

## 11. Gross domestic fixed investment: Nominal

$$R6009L = R6009D * (INP/100)$$

***GDP and GDE***

## 12. Gross domestic expenditure: Real

$$R6012D = R6007D + R6008D + R6009D + R6010D + ZGDE$$

## 13. Gross domestic expenditure excluding changes in inventories and residual item: Real

$$GDD = R6007D + R6008D + R6009D$$

## 14. Gross domestic expenditure: Nominal

$$R6012L = R6012D * (GDEP/100)$$

## 15. Gross domestic product: Real

$$R6006D = R6012D + R6013D - R6014D + ZGDP$$

## 16. Gross domestic product: Nominal

$$R6006L = R6012L + R6013L - R6014L$$

## 17. Net national income

$$NNI = R6006L - NRI6002L - R6004L + NRI6005L - (XFSN - MFSN)$$



TRADE AND THE BALANCE OF PAYMENTS

Exports

18. Merchandise exports: Real

♦ Long run equation

$$R5000D2 = \sum_{i=1}^3 \beta_i G7GDP_{(1-i)} + \sum_{j=4}^6 \beta_j R5352M_{(4-j)} + \beta_7 TREND_{(1984)} + \beta_8 XDUM2$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
Coefficient value	155.3	207.1	155.3	-39.53	-52.70	-39.53	149.8	2966
T value	11.00	11.00	11.00	-3.30	-3.30	-3.30	3.75	4.97

R2                    0.92  
D.W.                2.51  
Johansen        42.73 (1%:35.65)  
Test confirms 1 significant  
cointegration vector

♦ Short run equation

$$D(R5000D2) = \sum_{i=1}^3 \beta_i D(G7GDP_{(1-i)}) + \sum_{j=4}^6 \beta_j D(R5352M_{(4-j)}) + \beta_7 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
Coefficient value	216.5	288.7	216.5	-78.06	-104.08	-78.06	-1.30
T value	1.41	1.41	1.41	-2.39	-2.39	-2.39	-8.71

R2                    0.64  
D.W.                2.02

19. Exports of non-factor services: Real

◆ Long run equation

$$LOG(XNFSR) = \beta_1 LOG(R5000D2_{(-1)}) + \beta_2 LOG(R5003D_{(-2)}) + \beta_3 XSDUM + \beta_4 DUM89Q3$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$
<b>Coefficient value</b>	0.182	0.662	-0.028	0.142
<b>T value</b>	2.87	10.64	-3.27	7.31

**R2**                    **0.90**  
**D.W.**                **1.67**  
**Johansen**        **49.60 (1%:48.45)**  
**Test confirms 1 significant**  
**cointegration vector**

◆ Short run equation

$$DLOG(XNFSR) = \beta_1 DLOG(R5000D2_{(-1)}) + \beta_2 DLOG(R5003D_{(-2)}) + \beta_3 DUM92Q4 + \beta_4 DUM83Q4Q1 + \beta_5 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<b>Coefficient value</b>	0.128	0.244	0.098	-0.137	-0.64
<b>T value</b>	2.15	3.45	3.36	-3.27	-5.43

**R2**                    **0.62**  
**D.W.**                **2.24**

20. Gold price in rand

$$RB5356M = (RB5357M * R5339M / 100) + ZGOLDP$$



## 21. Net gold export: Nominal

$$R5001L = (GOLDP * 1000 / 32.1507 * RB5356M / 1000000) + ZGD$$

## 22. Exports of goods and non-factor services: Real

$$R6013D = (R5000D2 + XNFSR + GOLDP * 1000 / 32.1507 * 991.88 / 1000000) + ZX$$

## 23. Exports of goods and non-factor services: Nominal

$$R6013L = (R5000D2 + XNFSR) * (XP2 / 100) + R5001L$$

**Imports**

## 24. Merchandise imports: Real

## ♦ Long run equation

$$\begin{aligned} \text{LOG}(R5003D) = & \beta_0 + \sum_{i=1}^3 \beta_i \text{LOG}(MP_{(-i)} / R7050N_{(-i)}) + \sum_{j=4}^6 \beta_j \text{LOG}(R6012D_{(4-j)}) + \beta_7 XDUM \\ & + \beta_8 DUM86Q3 \end{aligned}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	-15.26	-0.123	-0.165	-0.123	0.580	0.774	0.580	0.036	0.214
<b>T value</b>	-5.13	-3.25	-3.25	-3.25	7.38	7.38	7.38	5.43	3.82

**R2**                      0.92  
**D.W.**                  1.36  
**Johansen**          65.94 (1%:48.45)  
**Test confirms 1 significant**  
**cointegration vector**

◆ *Short run equation*

$$DLOG(R5003D) = \sum_{i=1}^3 \beta_i DLOG(R6012D_{(1-i)}) + \beta_4 D(DUM86Q1) + \beta_5 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<i>Coefficient value</i>	0.801	1.067	0.801	0.271	-0.80
<i>T value</i>	5.41	5.41	5.41	8.71	-5.99

*R2*                    *0.75*  
*D.W.*                *1.77*

25.    Merchandise imports: Nominal

$$R5003L = R5003D * (MP/100)$$

26.    Imports of non-factor services: Real

◆ *Long run equation*

$$LOG(MNFSR) = \beta_0 + \beta_1 LOG(R5003D) + \beta_2 DUM90$$

	$\beta_0$	$\beta_1$	$\beta_2$
<i>Coefficient value</i>	2.637	0.609	0.204
<i>T value</i>	3.22	7.91	7.39

*R2*                    *0.85*  
*D.W.*                *1.53*  
*Johansen*        *26.73 (5%:25.32)*  
*Test confirms 1 significant*  
*cointegration vector*



♦ *Short run equation*

$$DLOG(MNFSR) = \beta_1 DLOG(R5003D) + \beta_2 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$
<b>Coefficient value</b>	0.386	-0.67
<b>T value</b>	2.94	-4.73

**R2**                      **0.34**

**D.W.**                    **2.14**

## 27. Imports of goods and non-factor services: Real

$$R6014D = R5003D + MNFSR$$

## 28. Imports of goods and non-factor services: Nominal

$$R6014L = R6014D * (MP/100)$$

***Balance of Payments***

## 29. Current account

$$RB5007L = R6013L - R6014L + (XFSN - MFSN) + R5006L$$

## 30. Long term capital movements of the non-monetary private sector

♦ *Long run equation*

$$(R5014I / R6006L) = \beta_0 + \beta_1 DUM93 * (E(BRQ_{(+1)}) - E(USLIB_{(+1)})) + \sum_{i=2}^4 \beta_i (INF_{(2-i)} - INFUS_{(2-i)}) \\ + \beta_5 DUM86Q4 + \beta_6 DUM94Q2$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<b>Coefficient value</b>	0.017	0.001	-0.001	-0.001	-0.001	-0.026	-0.020
<b>T value</b>	3.67	2.13	-4.84	-4.84	-4.84	-3.73	-3.03

**R2**                    **0.72**

**D.W.**                **1.93**

**Johansen**        **49.57 (1%:41.07)**

**Test confirms 1 significant  
cointegration vector**

♦ *Short run equation*

$$D(R5014L / R6006L) = \sum_{i=1}^3 \beta_i D(INF_{(1-i)} - INFUS_{(1-i)}) + \beta_4 ECT_{(-1)} + \beta_5 D(DUM86Q4) + \beta_6 D(DUM94Q2)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<b>Coefficient value</b>	-0.0004	-0.0006	-0.0004	-0.97	-0.032	-0.018
<b>T value</b>	-1.56	-1.56	-1.56	-6.46	-7.16	-4.02

**R2**                    **0.76**

**D.W.**                **1.87**

31. Long term capital movement : Total

$$R5008L = (RB5009K + RB5012K + RB5013K) * 4 + R5014L$$

32. Total capital movement

$$TOTC = R5008L + R5016L$$

33. Change in net gold and other foreign reserves owing to balance of payments transactions

$$R5020L = RB5007L + TOTC$$



<b>EXCHANGE RATES</b>
-----------------------

34. Rand/US\$ spot rate

♦ Long run equation

$$R5339M = \beta_0 + \sum_{i=1}^3 \beta_i (R5020L_{(1-i)} / R6006L_{(1-i)}) + \beta_4 R5339M_{(-1)} + \beta_5 (E(USCPI_{(+1)}) / E(CPI_{(+1)})) \\ + \beta_6 (E(BRQ_{(+1)}) / E(USLIB_{(+1)})) + \beta_7 DUM86Q1 + \beta_8 DUM86Q2Q3$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	300	-81.35	-108.5	-81.35	0.654	-120.9	-8.924	-64.43	38.85
<b>T value</b>	7.31	-3.00	-3.00	-3.00	11.29	-7.11	-3.23	-7.71	5.07

**R2**                    **0.98**  
**D.W.**                **1.95**  
**Johansen**        **65.98 (1%:54.46)**  
**Test confirms 1 significant**  
**cointegration vector**

♦ Short run equation

$$D(R5339M) = \sum_{i=1}^3 \beta_i D(R5020L_{(1-i)} / R6006L_{(1-i)}) + \beta_4 D(R5339M_{(-1)}) + \beta_5 D(E(USCPI_{(+1)}) / E(CPI_{(+1)})) \\ + \beta_6 D(ECT_{(-1)}) + \beta_7 D(DUM86Q1) + \beta_8 D(DUM86Q2Q3) + \beta_9 D(DUM83Q4Q1)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	-78.68	-104.9	-78.68	0.730	-143.1	-1.11	-71.17	33.61
<b>T value</b>	-1.94	-1.94	-1.94	5.70	-3.01	-5.97	-7.40	4.21

	$\beta_9$
<b>Coefficient value</b>	20.28
<b>T value</b>	2.15

***R2***                      ***0.72***  
***D.W.***                    ***1.89***

35. Rand/DM spot rate

$$RB5314M = \left( \frac{1}{EXDM\$} \right) * R5339M$$

36. Rand/Yen spot rate

$$RB5319M = \left( \frac{1}{EXYEN\$} \right) * R5339M$$

37. Rand/Pound spot rate

$$RB5338M = \left( \frac{1}{EXPO\$} \right) * R5339M$$

38. Effective exchange rate : nominal

$$R5350M = \left( \begin{array}{l} 0.517 * (1 / (R5339M * 100 / 258.77)) \\ + 0.172 * (1 / (RB5314M * 100 / 160.46)) \\ + 0.109 * (1 / (RB5319M * 100 / 1.793)) \\ + 0.202 * (1 / (RB5338M * 100 / 461.45)) \end{array} \right) * 10000 + ZEXN$$

39. Effective exchange rate: real

$$R5352M = \left( \begin{array}{l} 0.517 * (1 / (R5339M * 100 / 258.77)) * (CPI / USCPI) \\ + 0.172 * (1 / (RB5314M * 100 / 160.46)) * (CPI / GERCPI) \\ + 0.109 * (1 / (RB5319M * 100 / 1.793)) * (CPI / JAPCPI) \\ + 0.202 * (1 / (RB5338M * 100 / 461.45)) * (CPI / UKCPI) \end{array} \right) * 10000 + ZEXR$$



**GENERAL GOVERNMENT*****Current income of general government***

## 40. Direct personal tax

$$NRI6245L = NRI6244L * PTR$$

## 41. Direct corporate tax

$$NRI6230L = CTR * (NNI - R6240L - NRI6250L)$$

## 42. Indirect taxes

$$R6004L = ITR * (R6007L + R6009L + R5003L)$$

## 43. Other income

$$GOY = NRI6250L + NRI6252L + NRI6232L + NRI6253L$$

## 44. Current income

$$NRI6254L = NRI6245L + NRI6230L + R6004L + GOY$$

***Expenditure by general government***

## 45. Interest on public debt

$$GINT = GINT(-4) + ((DEF * (-1) - TBA) + DISCOUNT) * ACOUPON \\ + TBA * (TB/100) + ZGINT$$

## 46. Discount on required new stock issues

$$DISCOUNT = NEWSTOCK - (DEF * (-1) - TBA)$$

## 47. New stock issues required

$$NEWSTOCK = (DEF * (-1) - TBA) / ((ACOUPON / (RB2003M / 100)) - (1 / (1 + (RB2003M / 100))^{MATURE}) * ACOUPON / (RB2003M / 100)^{-1}))$$

## 48. Consumption expenditure: nominal

$$R6008L = R6008D * (GP / 100)$$

## 49. Transfers to households and rest of the world

$$GTRAN = NRI6257L + NRI6258L$$

## 50. Current expenditure

$$NRI6259L = GINT + R6008L + GTRAN + NRI6005L$$

## 51. Gross domestic fixed investment by public authorities: nominal

$$RB6100L = RB6100D * (INP / 100)$$

## 52. Total expenditure

$$TOTG = NRI6259L + R6100L$$



*Dissaving and deficit by general government*

53. Dissaving

$$GSAV = NRI6254L - NRI6259L$$

54. Deficit

$$DEF = GSAV - RB6100L + ZDEF$$

<b>EMPLOYMENT AND INCOME</b>
------------------------------

55. Employment in the non-agricultural private sector

◆ *Long run*

$$\begin{aligned} \text{Log}(PEM) = & \sum_{i=1}^3 \beta_i \text{Log}(R6006D - R6009D)_{(1-i)} + \sum_{j=4}^6 \beta_j \text{Log}(WRR_{(3-j)}) \\ & + \sum_{l=7}^9 \beta_l \text{Log}(R6009D)_{(6-l)} + \beta_{10} TREND_{1984} + \beta_{11} \text{Log}(PEM_{(-1)}) \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$	$\beta_9$
<i>Coefficient value</i>	0.083	0.110	0.083	-0.045	-0.061	-0.045	0.016	0.023	0.016
<i>T value</i>	4.95	4.95	4.95	-3.29	-3.29	-3.29	3.55	3.55	3.55

	$\beta_{10}$	$\beta_{11}$
<i>Coefficient value</i>	-0.001	0.703
<i>T value</i>	-3.14	13.26

**R2**                      **0.99**  
**D.W.**                   **1.40**  
**Johansen**           **60.99 (1%:54.46)**  
**Test confirms 1 significant**  
**cointegration vector**

◆ *Short run*

$$\begin{aligned}
 DLog(PEM) = & \sum_{i=1}^3 \beta_i DLog(R6006D - R6009D)_{(1-i)} + \sum_{j=4}^6 \beta_j DLog(WRR_{(3-j)}) \\
 & + \sum_{l=7}^9 \beta_l DLog(R6009D)_{(6-l)} + \beta_{10} DLog(PEM_{(-1)}) + \beta_{11} ECT_{(-1)}
 \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$	$\beta_9$
<b>Coefficient value</b>	0.052	0.069	0.052	-0.059	-0.079	-0.059	0.026	0.037	0.026
<b>T value</b>	2.01	2.01	2.01	-2.34	-2.34	-2.34	2.86	2.86	2.86

	$\beta_{10}$	$\beta_{11}$
<b>Coefficient value</b>	0.760	-0.78
<b>T value</b>	5.34	-3.87

**R2**                      **0.60**  
**D.W.**                   **1.94**

56. Total employment in the non-agricultural formal sector

$$TOTEMP = PEM + GEM$$

57. Wage rate: Real

◆ *Long run equation*

$$\begin{aligned}
 WRR = & \sum_{i=1}^3 \beta_i (R6006D_{(1-i)} / TOTEMP_{(1-i)}) + \sum_{j=4}^6 \beta_j (1 / RB7010N_{(-j)}) + \beta_7 Trend_{(1984)} \\
 & + \beta_8 D84 + \beta_9 D94 + \beta_{10} DWRR
 \end{aligned}$$



	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	0.131	0.174	0.131	51.76	69.02	51.76	0.0001
<b>T value</b>	46.09	46.09	46.09	5.63	5.63	5.63	10.68

	$\beta_8$	$\beta_9$	$\beta_{10}$
<b>Coefficient value</b>	0.001	-0.0007	0.0008
<b>T value</b>	6.23	-3.49	4.66

**R2**                    **0.97**  
**D.W.**                **1.61**  
**Johansen**        **45.03 (5%:42.44)**  
**Test confirms 1 significant**  
**cointegration vector**

◆ *Short run equation*

$$D(WRR) = \sum_{i=1}^3 \beta_i D(R6006D_{(1-i)} / TOTEMP_{(1-i)}) + \sum_{j=4}^6 \beta_j D(1 / RB7010N_{(4-j)}) + \beta_7 D(DUM86Q2) + \beta_8 D(DWRR) + \beta_9 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$	$\beta_9$
<b>Coefficient value</b>	0.126	0.168	0.126	22.81	30.41	22.81	0.0005	0.0004	-0.39
<b>T value</b>	2.88	2.88	2.88	1.14	1.14	1.14	2.24	1.92	-2.11

**R2**                    **0.39**  
**D.W.**                **1.70**

58. Personal savings

$$RB6200L = R6246L - R6007L - NRI6252L - NRI6248L$$

## 59. Unemployment in the non-agricultural formal sector

$$RB7010N = LFORCE - TOTEMP$$

## 60. Wage bill: Real

$$RWB = TOTEMP * WRR$$

## 61. Wage bill: Nominal

$$R6240L = RWB * CPI / 100$$

## 62. Disposable wage bill: Nominal

$$DWB = R6240L * (1 - PTR)$$

## 63. Disposable wage bill: Real

$$RDWB = DWB / CPI * 100$$

## 64. Private income excluding wage bill

$$POY = NRI6241L + TRANS$$

## 65. Current income: Nominal

$$NRI6244L = R6240L + POY$$

## 66. Personal disposable income: Nominal

$$R6246L = NRI6244L * (1 - PTR)$$



67. Personal disposable income: Real

$$RDISA = (R6246L / CPI) * 100$$

68. After tax real income from property by households

$$YPHH = \left( \frac{NRI6241L * (1 - PTR)}{CPI} \right) * 100$$

## MONETARY SECTOR

### *Interest rates*

69. Bank rate

#### ◆ *Long run equation*

$$BRQ = \beta_1(PCH(CRED_{(-2)}) - PCH(CP_{(-2)})) + \beta_2 R5352M_{(-2)} + \beta_3 PCH(CP_{(-2)}) \\ + \beta_4 USLIB + \beta_5 BRQ_{(-1)} + \beta_6 DUM85234 + \beta_7 DUM85Q3$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	38.66	-0.015	29.12	0.093	0.979	-1.697	-2.36
<b>T value</b>	4.44	-2.87	2.22	1.93	36.40	-4.85	-3.95

**R2**                    **0.98**  
**D.W.**                **2.68**  
**Johansen**        **86.52 (1%:84.45)**  
**Test confirms 1 significant**  
**cointegration vector**

◆ *Short run equation*

$$D(BRQ) = \beta_1 D(PCH(CRED_{(-2)}) - PCH(CP_{(-2)})) + \beta_2 D(R5352M_{(-2)}) + \beta_3 D(PCH(CP_{(-2)})) + \beta_4 ECT_{(-1)} + \beta_5 D(BRQ_{(-1)}) + \beta_6 D(DUM84Q2) + \beta_7 D(DUM85Q3) + \beta_8 D(DUM85234)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	43.66	-0.033	44.17	-1.30	1.02	-1.15	-2.27	-1.12
<b>T value</b>	6.07	-3.22	4.62	-9.67	18.51	-4.36	-7.67	-4.27

**R2**                    **0.91**  
**D.W.**                **1.74**

70.    Yield on 3 month Treasury Bills

$$TB = \beta_1 BRQ + \beta_2 (TB_{(-1)} - BRQ_{(-1)})$$

	$\beta_1$	$\beta_2$
<b>Coefficient value</b>	0.99	0.829
<b>T value</b>	201.0	10.6

**R2**                    **0.99**  
**D.W.**                **1.96**

71.    Mortgage rate

$$RILQ22 = \beta_1 BRQ + \beta_2 (RILQ22_{(-1)} - BRQ_{(-1)})$$

	$\beta_1$	$\beta_2$
<b>Coefficient value</b>	1.024	0.898
<b>T value</b>	108.5	20.51

**R2**                    **0.99**  
**D.W.**                **2.17**



## 72. Prime rate

$$RINT10Q = \beta_1 BRQ + \beta_2 (RINT10Q_{(-1)} - BRQ_{(-1)})$$

	$\beta_1$	$\beta_2$
<b>Coefficient value</b>	1.021	0.891
<b>T value</b>	74.49	13.92

**R2**                      **0.88**  
**D.W.**                  **1.96**

## 73. Yield on long-term government stock

## ◆ Long-run equation

$$RB2003M = \beta_0 + \sum_{i=1}^3 \beta_i (GSAV_{(1-i)} / R6006L_{(1-i)}) + \sum_{j=4}^6 \beta_j (R5020L_{(4-j)} / R6006L_{(4-j)}) \\ + \beta_7 (E(CPI_{(+1)}) / CPI_{(-3)}) + \beta_8 RB2003M_{(-1)} + \beta_9 DUM86Q3 + \beta_{10} DUM93Q4 + \beta_{11} DUM94Q3$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	8.216	3.530	4.706	3.530	-5.136	-6.848	-5.136	18.29	0.338
<b>T value</b>	5.00	1.53	1.53	1.53	-2.24	-2.24	-2.24	2.71	2.86

	$\beta_9$	$\beta_{10}$	$\beta_{11}$
<b>Coefficient value</b>	-2.907	-1.720	1.690
<b>T value</b>	-3.85	-2.31	3.26

**R2**                      **0.73**  
**D.W.**                  **1.99**  
**Johansen**          **65.23 (1%:60.16)**  
**Test confirms 1 significant**  
**cointegration vector**

♦ *Short run equation*

$$D(RB2003M) = \sum_{i=1}^3 \beta_i D(R5020L_{(1-i)} / R6006L_{(1-i)}) + \beta_4 D(E(CPI_{(+1)}) / CPI_{(-3)}) + \beta_5 D(RB2003M_{(-1)}) \\ + \beta_6 ECT_{(-1)} + \beta_7 D(DUM93Q4) + \beta_8 D(DUM86Q3) + \beta_9 D(DUM94Q3)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$	$\beta_9$
<b>Coefficient value</b>	-6.784	-9.045	-6.784	9.260	0.549	-1.25	-1.563	-2.868	2.709
<b>T value</b>	-2.29	-2.29	-2.29	1.41	3.80	-5.95	-3.39	-5.59	3.98

**R2**                      **0.65**

**D.W.**                    **2.06**

**Money supply**

74. Credit referring to instalment sale, leasing finance and mortgage loans

♦ *Long run equation*

$$LOG(CRED / CP) = \beta_0 + \beta_1 LOG(CRED_{(-1)} / CP_{(-1)}) + \sum_{l=2}^4 \beta_l LOG(R6012D_{(1-l)}) \\ + \sum_{j=5}^7 \beta_j LOG(RINT10Q_{(3-j)} / CP_{(3-j)}) + \beta_8 D84Q12$$

	$\beta_1$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	-1.805	0.811	0.097	0.130	0.097	-0.009	-0.013	-0.009	0.049
<b>T value</b>	-2.95	20.48	4.46	4.46	4.46	-6.24	-6.24	-6.24	5.72

**R2**                      **0.99**

**D.W.**                    **1.97**

**Johansen**           **48.12 (1%:41.07)**

**Test confirms 1 significant  
cointegration**

**Vector**



◆ *Short run equation*

$$DLOG(CRED/CP) = \beta_1 DLOG(CRED_{(-1)}/CP_{(-1)}) + \sum_{l=2}^4 \beta_l DLOG(R6012D_{(1-i)}) + \beta_5 ECT_{(-1)} + \beta_6 D(DUM87Q1) + \beta_7 D(D84Q12)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<i>Coefficient value</i>	0.675	0.137	0.182	0.137	-0.700	-0.024	0.045
<i>T value</i>	5.50	3.12	3.12	3.12	-3.63	-3.05	3.98

*R2*                    *0.69*  
*D.W.*                *1.82*

75.    Credit referring to other loans and advances

◆ *Long run equation*

$$LOG(R1365MSA/CP) = \beta_1 LOG(R1365MSA_{(-1)}/CP_{(-1)}) + \beta_2 TREND_{(1984)} + \sum_{l=3}^5 \beta_l LOG(R6012D_{(4-i)}) + \sum_{j=6}^8 \beta_j LOG(BRQ_{(-3-j)}/CP_{(-3-j)})$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<i>Coefficient value</i>	0.661	-0.004	0.095	0.127	0.095	-0.015	-0.019	-0.015
<i>T value</i>	11.13	-5.33	5.94	5.94	5.94	-3.19	-3.19	-3.19

*R2*                    *0.90*  
*D.W.*                *2.20*  
*Johansen*        *48.57 (1%:48.45)*  
*Test confirms 1 significant*  
*cointegration vector*

◆ *Short run equation*

$$DLOG(R1365MSA / CP) = \beta_1 DLOG(R1365MSA_{(-1)} / CP_{(-1)}) + \sum_{i=2}^4 \beta_i DLOG(R6012D_{(1-i)}) + \beta_5 ECT_{(-1)} + \beta_6 DUM90Q3$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<i>Coefficient value</i>	0.685	0.128	0.171	0.128	-1.10	-0.032
<i>T value</i>	3.97	1.62	1.62	1.62	-4.77	-1.97

*R2*                    *0.53*  
*D.W.*                *2.04*

76.    Claims on the private sector

$$RB1347MSA = R1360MSA + R1361MSA + CRED + R1365MSA$$

77.    Net foreign assets: Cumulative flow

$$RB1380MSA = RB1380MSA_{(-1)} + (R5020L + RB5024L) / 4 + ZNFA$$

78.    M3 money supply

$$RB1374N = RB1347MSA + RB1367MSA + RB1380MSA + RB1381MSA + ZM3$$



PRICES

79. Producer price index

♦ Long run equation

$$\begin{aligned} \text{LOG}(R7050N) = & \beta_0 + \beta_1 DUM93Q2 + \sum_{i=2}^4 \beta_i \text{LOG}(ULC_{(1-i)}) + \sum_{j=5}^7 \text{LOG}(MP_{(j-4)}) \\ & + \sum_{l=8}^{10} \text{LOG}((1/RB7010N)_{(8-l)}) \end{aligned}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	5.752	-0.051	0.148	0.197	0.148	0.189	0.252	0.189
<b>T value</b>	39.28	-7.49	19.81	19.81	19.81	20.88	20.88	20.88

	$\beta_8$	$\beta_9$	$\beta_{10}$
<b>Coefficient value</b>	0.019	0.026	0.019
<b>T value</b>	5.59	5.59	5.59

**R2** 1.00  
**D.W.** 1.11  
**Johansen** 69.05 (1%:61.24)  
**Test confirms 1 significant cointegration equation**

♦ Short run equation

$$\begin{aligned} D\text{LOG}(R7050N) = & \beta_1 D(DUM92Q4) + \beta_2 D\text{LOG}(RB7050N_{(-1)}) + \sum_{i=3}^5 \beta_i D\text{LOG}(ULC_{(2-i)}) \\ & + \sum_{j=6}^8 \beta_j D\text{LOG}(MP_{(5-j)}) + \beta_9 ECT_{(-1)} \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$	$\beta_9$
<i>Coefficient value</i>	-0.025	0.469	0.087	0.116	0.087	0.071	0.094	0.071	-0.34
<i>T value</i>	-2.70	3.44	2.78	2.78	2.78	2.72	2.72	2.72	-3.06

*R2*                    **0.47**  
*D.W.*                **2.05**

80.    Consumer price index

◆ *Long run equation*

$LOG(CPI/(1 + ITR)) = \beta_1 LOG(R7050N) + \beta_2 LOG(CPI_{(-1)}/(1 + ITR_{(-1)}))$

	$\beta_1$	$\beta_2$
<i>Coefficient value</i>	0.127	0.877
<i>T value</i>	7.90	53.34

*R2*                    **1.00**  
*D.W.*                **1.91**  
*Johansen*        **29.03 (1%:24.6)**  
*Test confirms 1 significant*  
*cointegration equation*

◆ *Short run equation*

$DLOG(CPI/(1 + ITR)) = \beta_1 DLOG(R7050N) + \beta_2 DLOG(CPI_{(-1)}/(1 + ITR_{(-1)}))$   
 $+ \beta_3 D(DUM95Q3) + \beta_4 ECT_{(-1)}$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$
<i>Coefficient value</i>	0.331	0.690	-0.015	-0.650
<i>T value</i>	3.00	6.43	-2.58	-3.85

*R2*                    **0.56**  
*D.W.*                **1.97**



81. Private consumption deflator

♦ Long run equation

$$\begin{aligned} \text{LOG}(CP/(1 + ITR)) &= \beta_0 + \beta_1 D9212 \\ &+ \sum_{i=2}^4 \beta_i \text{LOG}(1/ RB7010N_{(2-i)}) + \sum_{j=5}^7 \beta_j \text{LOG}(ULC_{(4-j)}) + \sum_{l=8}^{10} \beta_l \text{LOG}(MP_{(8-l)}) \end{aligned}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<i>Coefficient value</i>	0.766	0.026	0.007	0.009	0.007	0.255	0.340	0.255
<i>T value</i>	5.61	2.74	2.01	2.01	2.01	41.26	41.26	41.26

	$\beta_0$	$\beta_0$	$\beta_1$
<i>Coefficient value</i>	0.063	0.084	0.063
<i>T value</i>	7.60	7.60	7.60

*R2*                    *1.00*  
*D.W.*                *1.16*  
*Johansen*        *72.28 (1%:61.24)*  
*Test confirms 1 significant*  
*cointegration equation*

♦ Short run equation

$$\begin{aligned} D\text{LOG}(CP/(1 + ITR)) &= \sum_{i=1}^3 \beta_i D\text{LOG}(1/ RB7010N_{(1-i)}) + \sum_{j=4}^6 \beta_j D\text{LOG}(ULC_{(3-j)}) + \sum_{l=7}^9 \beta_l D\text{LOG}(MP_{(7-l)}) \\ &+ \beta_{10} D(D9534) + \beta_{11} ECT_{(-1)} \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$	$\beta_8$
<i>Coefficient value</i>	0.018	0.025	0.018	0.277	0.369	0.277	0.049	0.066	0.049
<i>T value</i>	2.60	2.60	2.60	13.21	13.21	13.21	2.22	2.22	2.22

	$\beta_1$	$\beta_2$
<i>Coefficient value</i>	-0.025	-0.60
<i>T value</i>	-2.51	-4.61

**R2**                      **0.49**  
**D.W.**                   **1.67**

## 82. Government consumption deflator

### ♦ Long run equation

$$\text{LOG}(GP) = \beta_0 + \beta_1 \text{LOG}(R7050N) + \sum_{i=2}^4 \beta_i \text{LOG}(ULC_{(2-i)})$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$
<b>Coefficient value</b>	-2.146	0.543	0.160	0.213	0.160
<b>T value</b>	-9.69	12.62	14.63	14.63	14.63

**R2**                      **1.00**  
**D.W.**                   **1.33**  
**Johansen**          **42.96 (1%:40.49)**  
**Test confirms 1 significant**  
**cointegration equation**

### ♦ Short run equation

$$D\text{LOG}(GP) = \beta_1 D\text{LOG}(R7050N) + \sum_{i=2}^4 \beta_i D\text{LOG}(ULC_{(2-i)}) + \beta_5 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<b>Coefficient value</b>	0.429	0.192	0.256	0.192	-0.66
<b>T value</b>	2.76	4.43	4.43	4.43	-4.60

**R2**                      **0.38**  
**D.W.**                   **2.16**



## 83. Investment deflator

## ♦ Long run equation

$$\text{LOG}(\text{INP} / \text{INP}_{(-4)}) = \beta_1 \text{LOG}(\text{R7050N} / \text{R7050N}_{(-4)}) + \sum_{i=2}^4 \beta_i \text{LOG}(\text{MP}_{(1-i)} / \text{MP}_{(-3-i)}) + \beta_5 \text{AR}(1)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<b>Coefficient value</b>	0.668	0.108	0.144	0.108	0.741
<b>T value</b>	7.67	4.68	4.68	4.68	6.95

**R2**                    **0.94**

**D.W.**                **1.96**

**Johansen**        **54.53 (1%:41.07)**

**Test confirms 1 significant  
cointegration equation**

## ♦ Short run equation

$$\text{DLOG}(\text{INP} / \text{INP}_{(-4)}) = \beta_1 \text{DLOG}(\text{R7050N} / \text{R7050N}_{(-4)}) + \sum_{i=2}^4 \beta_i \text{DLOG}(\text{MP}_{(1-i)} / \text{MP}_{((-3)-i)}) + \beta_5 \text{ECT}_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<b>Coefficient value</b>	0.446	0.116	0.154	0.116	-0.275
<b>T value</b>	3.35	4.96	4.96	4.96	-1.79

**R2**                    **0.59**

**D.W.**                **1.85**

## 84. Export prices excluding gold

## ♦ Long run equation

$$\text{LOG}(\text{XP2}) = \sum_{i=1}^3 \beta_i \text{LOG}(\text{R7050N}_{(1-i)}) + \sum_{j=4}^6 \beta_j \text{LOG}(\text{R5350M}_{(4-j)})$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<i>Coefficient value</i>	0.136	0.182	0.136	-0.136	-0.181	-0.136
<i>T value</i>	90.85	90.85	90.85	-95.59	-95.59	-95.59

*R2*                    **1.00**  
*D.W.*                **1.59**  
*Johansen*        **43.55 (1%:40.49)**  
*Test confirms 1 significant*  
*cointegration equation*

◆ *Short run equation*

$$DLOG(XP2) = \sum_{i=1}^3 \beta_i DLOG(R7050N_{(1-i)}) + \sum_{j=4}^6 \beta_j DLOG(R5350M_{(4-j)})$$
$$+ \beta_7 ECT_{(-1)} + \beta_8 D(DUM89Q4)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<i>Coefficient value</i>	0.157	0.209	0.157	-0.119	-0.159	-0.119	-0.485	-0.059
<i>T value</i>	3.17	3.17	3.17	-3.61	-3.61	-3.61	3.53	3.30

*R2*                    **0.54**  
*D.W.*                **2.12**

85.    Export prices of goods and non-factor services

*XDEF*=*R6013L*/*R6013D*



## 86. Import deflator

## ♦ Long run equation

$$\begin{aligned} \text{LOG}(MP / MP_{(-4)}) = & \beta_0 + \sum_{i=1}^3 \beta_i \text{LOG}(R5350M_{(1-i)} / R5350m_{(-3-i)}) + \\ & \sum_{j=4}^6 \beta_j \text{LOG}(G7CPI_{(4-j)} / G7CPI_{(-j)}) + \beta_7 \text{DUM87Q3} + \beta_8 \text{D8687} \end{aligned}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	0.034	-0.171	-0.228	-0.171	0.048	0.064	0.048	0.107	-0.060
<b>T value</b>	6.35	-17.84	-17.84	-17.84	2.65	2.65	2.65	4.62	-4.95

**R2**                    **0.89**  
**D.W.**                **2.38**  
**Johansen**        **49.41 (1%:41.07)**  
**Test confirms 1 significant**  
**cointegration equation**

## ♦ Short run equation

$$\begin{aligned} \text{DLOG}(MP / MP_{(-4)}) = & \sum_{i=1}^3 \beta_i \text{DLOG}(R5350M_{(1-i)} / R5350m_{(-3-i)}) \\ & + \sum_{j=4}^6 \beta_j \text{DLOG}(G7CPI_{(4-j)} / G7CPI_{(-j)}) + \beta_7 \text{ECT}_{(-1)} \beta_8 \text{D}(\text{DUM87Q3}) + \beta_9 \text{D}(\text{DUM8687}) \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<b>Coefficient value</b>	-0.150	-0.200	-0.150	0.063	0.084	0.063
<b>T value</b>	-6.80	-6.80	-6.80	2.02	2.02	2.02

	$\beta_7$	$\beta_8$	$\beta_9$
<b>Coefficient value</b>	-1.231	0.110	-0.048
<b>T value</b>	-8.40	7.34	-3.21

**R2**                    **0.81**  
**D.W.**                **1.92**

## 87. Gross domestic expenditure deflator

## ♦ Long run equation

$$GDEP = \beta_1 CP + \beta_2 GP + \beta_3 INP + \beta_4 DUM92Q1 + \beta_5 DUM95Q3$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$
<b>Coefficient value</b>	0.442	0.491	0.061	0.022	0.037
<b>T value</b>	4.78	4.41	1.95	1.74	2.81

**R2** 1.00

**D.W.** 1.58

**Johansen** 63.98 (1%:60.16)

**Test confirms 1 significant  
cointegration equation**

## ♦ Short run equation

$$D(GDEP) = \beta_1 D(CP) + \beta_2 D(GP) + \beta_3 D(INP) + \beta_4 D(DUM86Q3) + \beta_5 D(DUM95Q3) + \beta_6 ECT_{(-1)}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$
<b>Coefficient value</b>	0.519	0.196	0.318	-0.024	0.045	-0.600
<b>T value</b>	3.11	1.70	1.72	-2.68	5.18	-3.59

**R2** 0.65

**D.W.** 2.20

## 88. GDP deflator

$$GDPDEF = R6006L/R6006D$$

## 89. Unit labour cost

$$ULC = R6240L/R6006D$$



<b>EXPECTATIONS</b>
---------------------

*Endogenous*

90. Bank rate: Period t

◆ *Long run equation*

$$E(BRQ) = \beta_1(PCH(CRED_{(-2)}) - PCH(CP_{(-2)})) + \beta_2 R5352M_{(-2)} + \beta_3 PCH(CP_{(-2)}) + \beta_4 E(USLIB) + \beta_5 BRQ_{(-1)} + \beta_6 DUM85234 + \beta_7 DUM85Q3$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	40.59	-0.016	30.89	0.087	0.978	-1.638	-2.36
<b>T value</b>	4.62	-2.84	2.27	1.61	34.78	-4.68	-3.86

R2                    **0.98**  
D.W.                **2.68**  
Johansen         **92.94 (1%:84.45)**  
Test confirms 1 significant  
cointegration vector

◆ *Short run equation*

$$D(E(BRQ)) = \beta_1 D(PCH(CRED_{(-2)}) - PCH(CP_{(-2)})) + \beta_2 D(R5352M_{(-2)}) + \beta_3 D(PCH(CP_{(-2)})) + \beta_4 ECT_{(-1)} + \beta_5 D(BRQ_{(-1)}) + \beta_6 DUM85234 + \beta_7 D(DUM85Q3) + \beta_8 D(DUM84Q2)$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	45.81	-0.03	47.15	-1.286	1.026	-1.067	-2.33	-1.206
<b>T value</b>	6.36	-3.21	4.94	-9.72	18.59	-4.08	-7.87	-4.61

R2                    **0.91**  
D.W.                **1.69**

## 91. Bank rate: Period t+1

$$D(E(BRQ_{(t+1)})) = \beta_1 D(PCH(CRED_{(-1)}) - PCH(CP_{(-1)})) + \beta_2 D(R5352M_{(-1)}) + \beta_3 D(PCH(CP_{(-1)})) \\ + \beta_4 E(BRQ) + \beta_5 ECT_{(-1)} + \beta_6 D(DUM85Q_{3(t+1)}) + \beta_7 D(DUM84Q_{3(t+1)}) + \beta_8 D(DUM85234_{(t+1)})$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<b>Coefficient value</b>	18.33	-0.023	28.11	0.940	-0.37	-2.016	2.935	-1.04
<b>T value</b>	1.84	-1.62	2.19	12.73	-2.18	-4.81	7.38	-2.87

R2 **0.83**D.W. **2.06**

## 92. Mortgage rate: Period t

$$E(RILQ22) = \beta_1 E(BRQ) + \beta_2 (RILQ22_{(-1)} - BRQ_{(-1)})$$

	$\beta_1$	$\beta_2$
<b>Coefficient value</b>	1.017	-0.907
<b>T value</b>	68.89	-13.14

R2 **0.86**D.W. **1.99**

## 93. Mortgage rate: Period t+1

$$E(RILQ22_{(t+1)}) = \beta_1 E(BRQ_{(t+1)}) + \beta_2 (E(RILQ22) - E(BRQ)) + \beta_3 DUM85$$

	$\beta_1$	$\beta_2$	$\beta_3$
<b>Coefficient value</b>	0.954	-0.502	2.330
<b>T value</b>	46.41	-4.30	4.57



**R2**                    **0.86**  
**D.W.**                **1.66**

94.     Consumer price index: Period t

♦   *Long run equation*

$$\begin{aligned} LOG(E(CPI/(1+ITR))) &= \beta_0 + \beta_1 LOG(CPI_{(-1)}/(1+ITR)) + \sum_{i=2}^4 \beta_i LOG(MP_{(-i)}) + \sum_{j=5}^7 \beta_j LOG(ULC_{(3-j)}) \\ &+ \beta_8 DUM92Q4 + \beta_9 DUM95Q3 \end{aligned}$$

	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$
<b>Coefficient value</b>	1.428	0.722	0.032	0.043	0.032	0.057	0.076	0.057
<b>T value</b>	3.30	8.43	3.49	3.49	3.49	2.93	2.93	2.93

	$\beta_8$	$\beta_9$
<b>Coefficient value</b>	-0.015	-0.023
<b>T value</b>	-3.62	-3.13

**R2**                    **1.00**  
**D.W.**                **1.87**  
**Johansen**        **46.17 (1%:41.07)**  
**Test confirms 1 significant**  
**cointegration vector**

♦   *Short run equation*

$$\begin{aligned} DLOG(E(CPI/(1+ITR))) &= \beta_1 DLOG(CPI_{(-1)}/(1+ITR_{(-1)})) + \sum_{i=2}^4 \beta_i DLOG(MP_{(-i)}) + \sum_{j=5}^7 \beta_j DLOG(ULC_{(3-j)}) \\ &+ \beta_8 ECT(-1) + \beta_9 D(DUM92Q4) + \beta_{10} D(DUM95Q3) \end{aligned}$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<i>Coefficient value</i>	0.683	0.057	0.076	0.057	0.051	0.068	0.051	-0.991
<i>T value</i>	5.66	3.49	3.49	3.49	1.57	1.57	1.57	-5.65

	$\beta_9$	$\beta_{10}$
<i>Coefficient value</i>	-0.022	-0.022
<i>T value</i>	-4.45	-3.30

*R*2                    0.68  
*D.W.*                1.93

95.     Consumer Price Index: Period t+1

$$DLOG\big(E(CPI_{(t+1)})/(1+ITR_{(t+1)})\big)) = \beta_1 DLOG\big(E(CPI/(1+ITR))\big)) + \sum_{i=2}^4 \beta_i DLOG(MP_{(-i)}) + \sum_{j=5}^7 \beta_j DLOG(ULC_{(3-j)}) + \beta_8 ECT_{(-1)} + \beta_9 D(DUM92Q4_{(t+1)}) + \beta_{10} D(DUM95Q3_{(t+1)})$$

	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$	$\beta_5$	$\beta_6$	$\beta_7$	$\beta_8$
<i>Coefficient value</i>	0.642	0.046	0.061	0.046	0.069	0.092	0.069	-0.593
<i>T value</i>	4.14	2.34	2.34	2.34	1.78	1.78	1.78	-3.30

	$\beta_9$	$\beta_{10}$
<i>Coefficient value</i>	-0.022	-0.022
<i>T value</i>	-3.93	-2.87

*R*2                    0.62  
*D.W.*                2.29

*Exogenous*

96.     US LIBOR rate: Period t+1

$$E(USLIB_{(t+1)}) = \beta_1 USLIB_{(-1)} + \beta_2 MA(1) + \beta_3 MA(2)$$



	$\beta_1$	$\beta_2$	$\beta_3$
<i>Coefficient value</i>	0.964	1.316	0.425
<i>T value</i>	29.60	10.02	3.51

*R2*                    *0.93*  
*D.W.*                *1.91*

97.    US CPI: Period t

$E(USCPI) = \beta_1 AR(1) + \beta_2 MA(1)$

	$\beta_1$	$\beta_2$
<i>Coefficient value</i>	1.009	0.420
<i>T value</i>	1463	3.13

*R2*                    *1.00*  
*D.W.*                *2.01*

## APPENDIX II

### DESCRIPTION OF DATA SERIES

#### SOURCE

SARB	South African Reserve Bank
DoF	Department of Finance
IFS	International Financial Statistics
BER	Bureau of Economic Research, University of Stellenbosch

CODE	DESCRIPTION	TYPE	SOURCE
ACoupon	Average coupon rate on long term government stock	%	DoF
BRQ	Bank Rate	%	SARB
CP	Price deflator: Private consumption expenditure	90=100	Generated
CPI	Consumer price index	90=100	SARB
CRED	Credit referring to leasing finance, instalment sales and mortgage advances	Nominal	Generated
CTR	Effective tax rate: Corporate	%/100	Generated
DEF	Deficit: General Government	Nominal	Generated
DISCOUNT	Discount on new long term stock issued	Nominal	Generated
DWB	Disposable wage bill	Nominal	Generated
ECT	Error Correction Term of long run equation		Generated
EXDM\$	Spot exchange rate: DM/US\$	Nominal	SARB
EXPO\$	Spot exchange rate: Pound/US\$	Nominal	SARB
EXYEN\$	Spot exchange rate: Yen/US\$	Nominal	SARB
G7CPI2	CPI of G7 OECD countries	90=100	IFS
G7GDP	GDP of G7 OECD countries	Real	IFS
GDD	GDE excluding changes in inventories	Real	Generated
GDEP	Price deflator: GDE	90=100	Generated
GDPDEF	Price deflator: GDP	90=100	Generated
GEM	Employment: Public authorities	Million	SARB
GERCPI	CPI: Germany	90=100	IFS
GINT	Interest on public debt: General government	Nominal	SARB
GOLDP	Gold production	kg	BER
GOY	Non tax income: General government	Nominal	SARB
GP	Price deflator: General government consumption exp.	90=100	Generated
GSAV	Saving: General government	Nominal	SARB
GTRAN	Transfers: General government	Nominal	SARB
INF	South Africa: CPI Inflation	%	Generated
INFUS	United States: CPI inflation	%	Generated
INP	Price deflator: Gross domestic fixed investment	90=100	Generated
IP	Private investment excluding residential investment	Real	Generated
IPR	Private residential investment	Real	Generated
ITR	Effective tax rate: Indirect	%/100	Generated
JAPCPI	CPI: Japan	90=100	IFS
LFORCE	Labour Force	Million	SARB
MATURE	Average maturity structure of long term debt: General government	Years	DoF
MFSN	Import of factor services	Nominal	Generated
MNFSR	Import of non factor services	Real	Generated
MP	Price deflator: Imports of goods and non-factor services	90=100	Generated



CODE	DESCRIPTION	TYPE	SOURCE
NEWSTOCK	New long term stock issues required: General government	Nominal	Generated
NNI	Net national income at factor cost	Nominal	Generated
NRI6002L	Provision for depreciation	Nominal	SARB
NRI6005L	Subsidies: General government	Nominal	SARB
NRI6230L	Direct taxes: Corporations	Nominal	SARB
NRI6232L	Current transfers received from corporations: General government	Nominal	SARB
NRI6241L	Income from property by households	Nominal	SARB
NRI6244L	Personal current income	Nominal	SARB
NRI6245L	Direct taxes: Personal	Nominal	SARB
NRI6248L	Transfers to the rest of the world: Personal	Nominal	SARB
NRI6250L	Income from property: General Government	Nominal	SARB
NRI6252L	Current transfers received from households: General Gov.	Nominal	SARB
NRI6253L	Transfers received from rest of the world: General Gov.	Nominal	SARB
NRI6254L	Current income: General government	Nominal	SARB
NRI6257L	Current transfers to households: General government	Nominal	SARB
NRI6258L	Transfers to the rest of the world: General government	Nominal	SARB
NRI6259L	Current expenditure: General government	Nominal	SARB
PEM	Employment: Non-agricultural private sector	Million	SARB
R1360MSA	Credit extended to the domestic private sector: Investments	Nominal	SARB
R1361MSA	Credit extended to the domestic private sector: Bills discounted	Nominal	SARB
POY	Non wage current income: Personal	Nominal	Generated
PTR	Effective tax rate: Personal direct	%/100	Generated
R1365MSA	Credit: Other loans and advances	Nominal	Generated
R1374N	Money supply: M3	Nominal	SARB
R5000D2	Merchandise exports	Real	SARB
R5000L	Merchandise exports	Nominal	SARB
R5001L	Net gold exports	Nominal	SARB
R5003D	Merchandise imports	Real	SARB
R5003L	Merchandise imports	Nominal	SARB
R5006L	Transfers of the current account	Nominal	SARB
R5008L	BOP: Long term capital movements: Total	Nominal	SARB
R5014K	BOP: Long term capital movements: Non-monetary private sector	Nominal	SARB
R5016K	BOP: Short term capital movements: Total	Nominal	SARB
R5020L	BOP: Change in net gold and other reserves	Nominal	SARB
R5339M	Rand/US\$ spot rate	Nominal	SARB
R5350M	Effective exchange rate	Nominal	SARB
R5352M	Effective exchange rate	Real	SARB
R6006D	Gross domestic product	Real	SARB
R6004L	Indirect taxes: General government	Nominal	SARB
R6006L	Gross domestic product	Nominal	SARB
R6007D	Private consumption expenditure: Total	Real	SARB
R6007L	Private consumption expenditure: Total	Nominal	SARB
R6008D	Consumption expenditure by general government	Real	SARB
R6008L	Consumption expenditure by general government	Nominal	SARB



CODE	DESCRIPTION	TYPE	SOURCE
R6009D	Gross domestic fixed investment	Real	SARB
R6009L	Gross domestic fixed investment	Nominal	SARB
R6010D	Change in inventories	Real	SARB
R6010L	Change in inventories	Nominal	SARB
R6012D	Gross domestic expenditure	Real	SARB
R6012L	Gross domestic expenditure	Nominal	SARB
R6013D	Exports of goods and non-factor services	Real	SARB
R6013L	Exports of goods and non-factor services	Nominal	SARB
R6014D	Imports of goods and non-factor services	Real	SARB
R6014L	Imports of goods and non-factor services	Nominal	SARB
R6050D	Private consumption expenditure: Durables	Real	SARB
R6055D	Private consumption expenditure: Semi-durables	Real	SARB
R6061D	Private consumption expenditure: Non-durables	Real	SARB
R6068D	Private consumption expenditure: Services	Real	SARB
R6240L	Remuneration of employees	Nominal	SARB
R6246L	Personal disposable income	Nominal	SARB
R7050N	Producer Price Index	90=100	SARB
RB1347MSA	Credit extended to the domestic private sector: Total	Nominal	SARB
RB1367MSA	Net claims on the government sector	Nominal	SARB
RB1380MSA	Net foreign assets: Cumulative flows	Nominal	SARB
RB1381MSA	Net other assets and liabilities	Nominal	SARB
RB2003M	Yield on long-term government stock	%	SARB
RB5007L	BOP: Current account	Nominal	SARB
RB5009K	BOP: Long term capital movements: Public authorities	Nominal	SARB
RB5012K	BOP: Long term capital movements: Public corporations	Nominal	SARB
RB5013K	BOP: Long term capital movements: Monetary sector	Nominal	SARB
RB5024L	Total capital movements not related to reserves	Nominal	SARB
RB5314M	Spot rate: DM/US\$	Q-avg	SARB
RB5319M	Spot rate: YEN/US\$	Q-avg	SARB
RB5338M	Spot rate: UK Pound/US\$	Q-avg	SARB
RB5356M	London gold price in rand	Q-avg	SARB
RB5357M	London gold price in US\$	Q-avg	SARB
RB6100D	Public authorities: Gross domestic fixed investment	Real	SARB
RB6100L	Public authorities: Gross domestic fixed investment	Nominal	SARB
RB6106D	Public corporations: Gross domestic fixed investment	Real	SARB
RB6200L	Saving: Personal	Nominal	SARB
RB7010N	Unemployment in the non-agricultural sector	Million	SARB
RDISA	Disposable income	Real	Generated
RDWB	Disposable wage bill	Real	Generated
RILQ22	Mortgage rate	%	SARB
RINT10Q	Prime rate	%	SARB
RWB	Wage bill	Real	Generated
TB	Yield on 3 months Treasury Bills	%	SARB
TBA	Amount of total borrowing financed by treasury bills	Nominal	SARB
TOTC	BOP: Short and long term capital movements	Nominal	Generated
TOTEMP	Total employment in the non-agricultural sector	Million	SARB
TOTG	Total expenditure: General government	Nominal	SARB
TRANS	Transfers received by households	Nominal	SARB
UKCPI	UK: CPI	90=100	IFS
ULC	Unit labour cost	Nominal	Generated
USCPI	US: CPI	90=100	IFS



CODE	DESCRIPTION	TYPE	SOURCE
USLIB	3 month US\$ LIBOR	%	IFS
WRR	Wage rate	Real	Generated
XDEF	Price deflator: Exports of goods and non-factor services	90=100	Generated
XFSN	Exports of factor services	Nominal	Generated
XNFSR	Exports of non-factor services	Real	Generated
XP2	Price deflator: Exports excluding gold	90=100	SARB
YPHH	After tax income from property by households	Real	SARB
ZC	Statistical discrepancy due to base year change	-	Generated
ZEXN	Statistical discrepancy	-	Generated
ZEXR	Statistical discrepancy	-	Generated
ZDEF	Residual item	-	Generated
ZGD	Statistical discrepancy	-	Generated
ZGDE	Residual item	-	Generated
ZGDP	Statistical discrepancy due to base year change	-	Generated
ZGINT	Residual item	-	Generated
ZGOLDP	Statistical discrepancy	-	Generated
ZI	Residual item	-	Generated
ZM3	Statistical discrepancy	-	Generated
ZNFA	Residual item	-	Generated
ZX	Statistical discrepancy	-	Generated

#### DUMMY VARIABLES

DUM83Q4Q1	Dummy variable (=1 in 1983Q4 and 1984Q1)	-	Generated
DUM84Q2	Dummy variable (=1 in 1984Q2)	-	Generated
D84Q12	Dummy variable (=1 in 1984Q1 and 1984Q2)	-	Generated
D84	Dummy variable (=1 between 1984Q2 and 1985Q1)	-	Generated
DUM85234	Dummy variable (=1 between 1985Q2 and 1986Q1)	-	Generated
DUM85	Dummy variable (=1 in 1985Q1 onwards)	-	Generated
DUM85Q3	Dummy variable (=1 in 1985Q3)	-	Generated
DUM85Q4	Dummy variable (=1 in 1985Q4)	-	Generated
DUM86Q1	Dummy variable (=1 in 1986Q1 onwards)	-	Generated
DUM86Q2	Dummy variable (=1 in 1986Q2 onwards)	-	Generated
DUM86Q3	Dummy variable (=1 in 1986Q3)	-	Generated
DUM86Q4	Dummy variable (=1 in 1986Q4)	-	Generated
DUM86Q2Q3	Dummy variable (=1 in 1986Q2 and 1986Q3)	-	Generated
D8687	Dummy variable (=1 between 1986Q2 and 1987Q1)	-	Generated
DUM87Q1	Dummy variable (=1 in 1987Q1)	-	Generated
DUM87Q3	Dummy variable (=1 in 1987Q3)	-	Generated
DUM88Q1	Dummy variable (=1 in 1988Q1)	-	Generated
DUM89Q3	Dummy variable (=1 in 1989Q3)	-	Generated
DUM89Q4	Dummy variable (=1 in 1989Q4)	-	Generated
DUM90	Dummy variable (=1 in 1990Q1 onwards)	-	Generated
DUM90Q3	Dummy variable (=1 in 1990Q3)	-	Generated
DUM91Q1	Dummy variable (=1 in 1991Q1)	-	Generated
D9212	Dummy variable (=1 in 1992Q1 and 1992Q2)	-	Generated
DUM92Q1	Dummy variable (=1 in 1992Q1)	-	Generated
DUM92Q4	Dummy variable (=1 in 1992Q4 onwards)	-	Generated
DUM93	Dummy variable (=1 in 1993Q1 onwards)	-	Generated
DUM93Q2	Dummy variable (=1 in 1993Q2)	-	Generated
DUM93Q4	Dummy variable (=1 in 1993Q4)	-	Generated
D94Q1	Dummy variable (=0 until 1993Q4, then trend)	-	Generated

**DUMMY VARIABLES**

DUM94Q1	Dummy variable (=1 in 1994Q1)	-	Generated
DUM94Q2	Dummy variable (=1 in 1994Q2)	-	Generated
DUM95Q3	Dummy variable (=1 in 1995Q3)	-	Generated
DUM94Q3	Dummy variable (=1 in 1994Q3 onwards)	-	Generated
DWRR	Dummy variable (=1 between 1992Q4 and 1993Q3)	-	Generated
D9534	Dummy variable (=1 in 1995Q3 and 1995Q4)	-	Generated
D94	Dummy variable (=1 between 1994Q4 and 1995Q3)	-	Generated
XDUM	Dummy variable (=0 until 1993Q1, then trend: 1, 1.5, 2...)	-	Generated
XDUM2	Dummy variable (=0 until 1994Q3, then trend: 1, 1.5, 2...)	-	Generated
XSDUM	Dummy variable (=0 until 1994Q3, then trend 1, 2, 3..)	-	Generated



### APPENDIX III

#### TEST FOR STATIONARITY OF TIME SERIES

To test for the order of integration of the time series, the Phillips-Perron test procedure was predominantly applied. For a number of series, the Augmented Dickey-Fuller test provided different results to the Phillips-Perron tests. In these cases, both test statistics are stated. However, for most series, both tests either confirmed or rejected the presence of a unit root. The sample period is equivalent to the estimation period namely 1984Q1 to 1995Q4 and relevant 5% critical values are provided. The following abbreviations are used:

PP : Phillips-Perron test

ADF: Augmented Dickey-Fuller test

I(1): The time series is integrated of order one

PCH(X):Percentage change in X

LOG(X):Natural log of X

D(X): First differences of X

Variable	PP Test on Level	5% Critical value	PP test on first differences	5% Critical value	Order of integration
<b>BRQ</b>	-1.85	-2.92	-3.32	-2.92	I(1)
<b>CP</b>	-2.95	-3.51	-4.53	-3.51	I(1)
<b>CPI</b>	-2.8	-3.51	-4.85	-3.51	I(1)
<b>D(CRED)</b>	-1.93	-3.51	-8.47	-3.51	I(1)
<b>PCH(CRED)</b>	-2.82	-2.92	-8.08	-2.92	I(1)
<b>PCH(CRED)- PCH(CPI)</b>	-2.86	-2.92	-8.79	-2.92	I(1)
<b>G7GDP</b>	-2.18	-2.92	-4.4	-2.92	I(1)
<b>G7CPI</b>	-1.73	-2.92	-5.11	-2.92	I(1)

Variable	PP Test on Level	5% Critical value	PP test on first differences	5% Critical value	Order of integration
GDD	-1.49	-3.51	-5.83	-3.51	I(1)
LOG(GDD/ GDD(-3))	-2.16	-2.92	-6.27	-2.92	I(1)
GDEP	-3.1	-3.51	-9.77	-3.51	I(1)
GP	-1.72	-3.51	-9.85	-3.51	I(1)
GSAV	-1.02	-2.92	-7.04	-2.92	I(1)
INP	-3.43	-3.51	-5.08	-3.51	I(1)
IP	-0.98	-2.92	-7.03	-2.92	I(1)
IPR	-1.87	-2.92	-7.01	-2.92	I(1)
MNFSR	-0.06	-2.92	-13.27	-2.92	I(1)
MP	-0.46	-2.92	-10.75	-2.92	I(1)
MP/CPI	-0.45	-2.92	-9.5	-2.92	I(1)
PEM	-0.18	-2.92	-3.17	-2.92	I(1)
R1347N	-1.2	-3.51	-4.9	-3.51	I(1)
LOG(R1347N/ R1347N(-4))	-1.9	-3.51	-3.87	-3.51	I(1)
R1365MSA/CP	-2.22	-2.92	-5.35	-2.92	I(1)
CRED/CP	-0.97	-3.51	-3.51	-3.51	I(1)
RB2003Q	-0.07	-1.95	-6.89	-1.95	I(1)
R5000D2	-0.28	-2.92	-13.57	-2.92	I(1)
R5003D	-1.4	-3.51	-9.65	-3.51	I(1)
R5014I/R6006L	-4.36 ADF: -2.47	-2.92	-12.45 ADF: -4.08	-2.92	I(1)*
R5339M	-1.53	-2.92	-6.9	-2.92	I(1)
R5352M	-0.86	-1.94	-6.45	-1.94	I(1)
R6010D	-4.25 ADF: -2.04	-2.92	-13.78 ADF: -4.61	-2.92	I(1)*
R6050D	-2.62	-2.92	-8.12	-2.92	I(1)
R6055D	-1.92	-3.51	-7.62	-3.51	I(1)
R6061D	-1.42	-2.92	-5.38	-2.92	I(1)
R6068D	-0.36	-2.92	-7.97	-2.92	I(1)
R6106D	-1.79	-2.92	-8.74	-2.92	I(1)
R7050N	-3.17	-3.51	-6.28	-3.51	I(1)
RDISA	-0.62	-2.92	-8.16	-2.92	I(1)
RDWB	-1.27	-2.92	-9.92	-2.92	I(1)
RILQ22	-1.85	-2.92	-5.91	-2.92	I(1)
RINT10Q	-1.86	-2.92	-3.24	-2.92	I(1)
TB	-1.82	-2.92	-3.47	-2.92	I(1)
TOTEMP	-1.31	-2.92	-3.72	-2.92	I(1)
ULC	-2.37	-3.51	-4.38	-3.51	I(1)

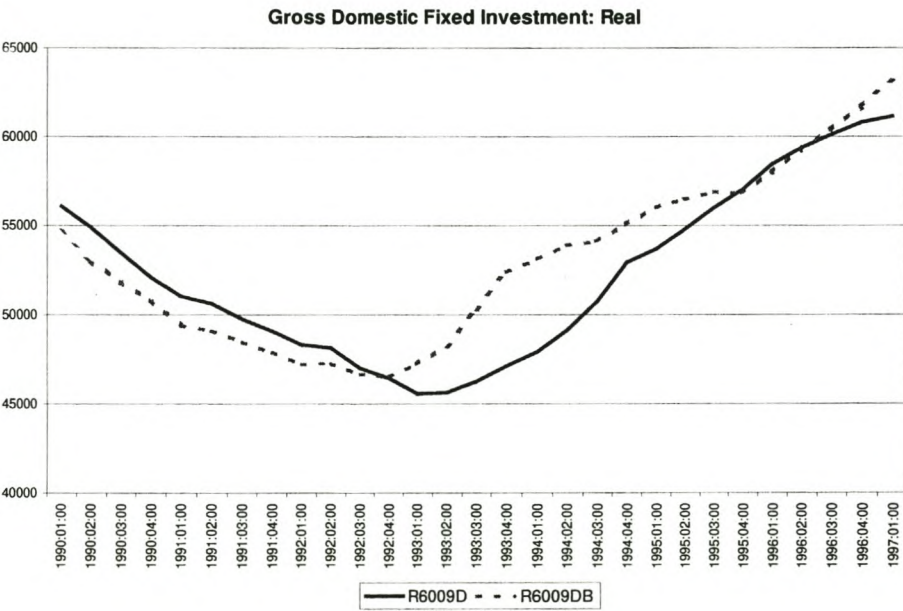
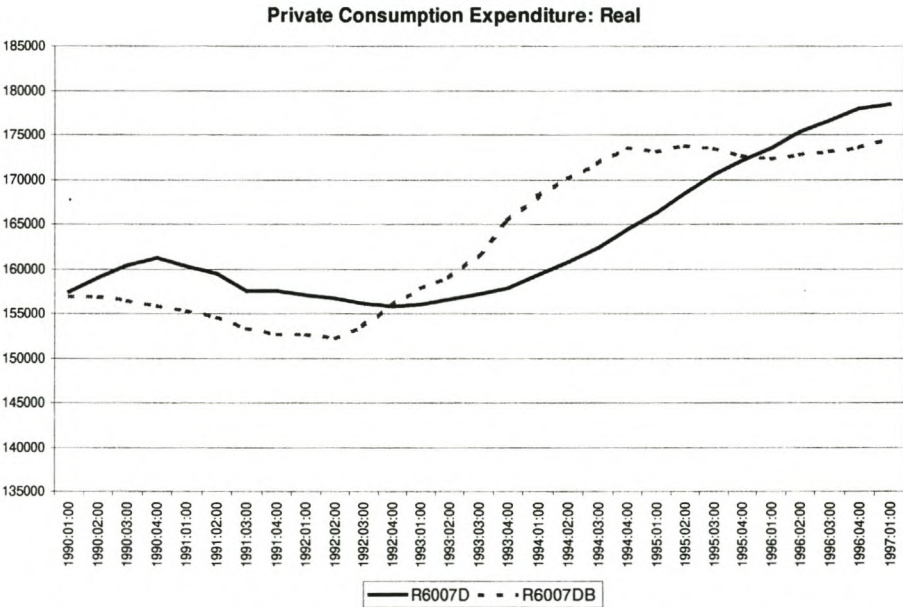
\* The possibility of an I(0) process cannot be excluded according to the Phillips-Perron test.



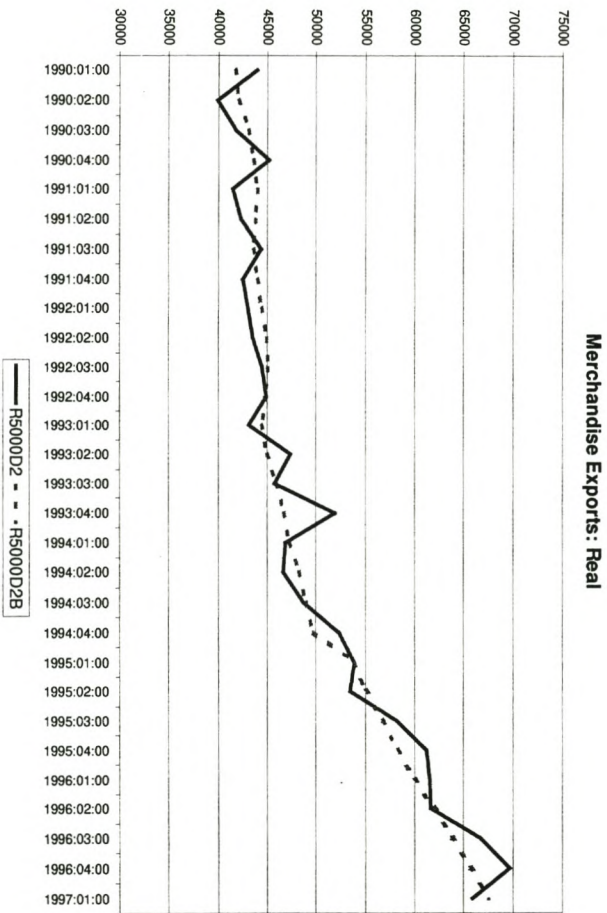
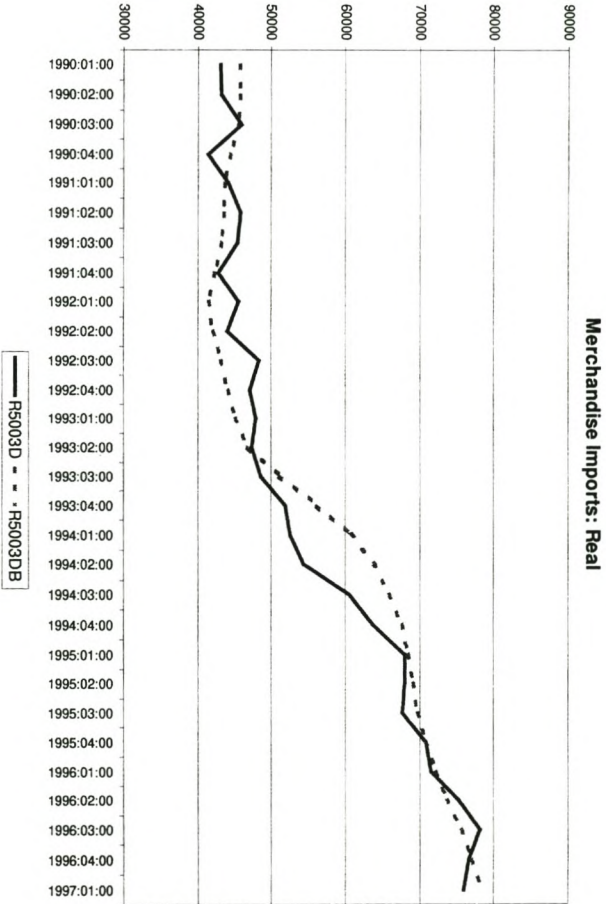
Variable	PP Test on Level	5% Critical value	PP test on first differences	5% Critical value	Order of integration
WRR	-1.45	-3.51	-7.22	-3.51	I(1)
XNFSR	-0.23	-2.92	-7.92	-2.92	I(1)
XP2	-0.77	-2.92	-9.02	-2.92	I(1)

APPENDIX IV  
DYNAMIC SIMULATION 1990Q1 TO 1997Q1  
MODEL SOLUTION =EXTENSION 'B'

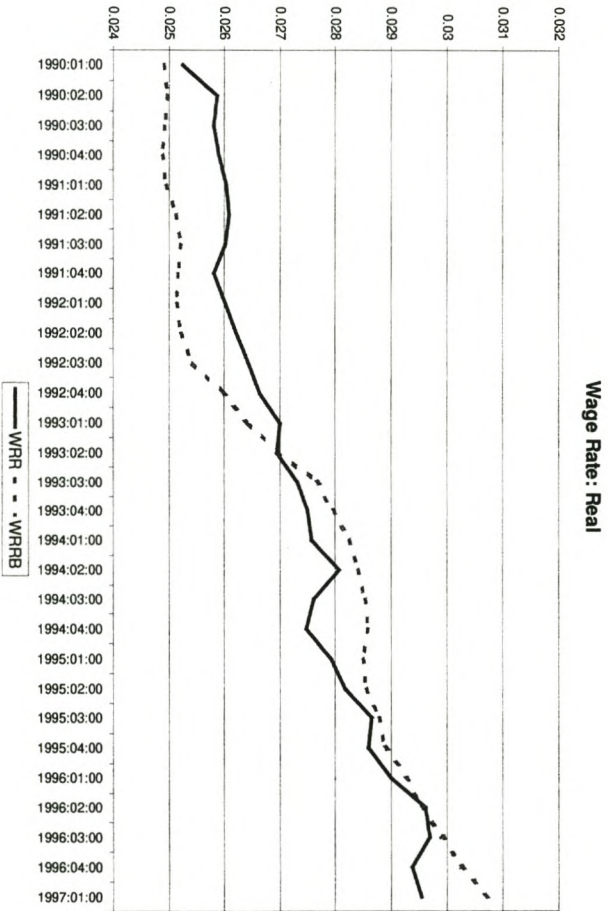
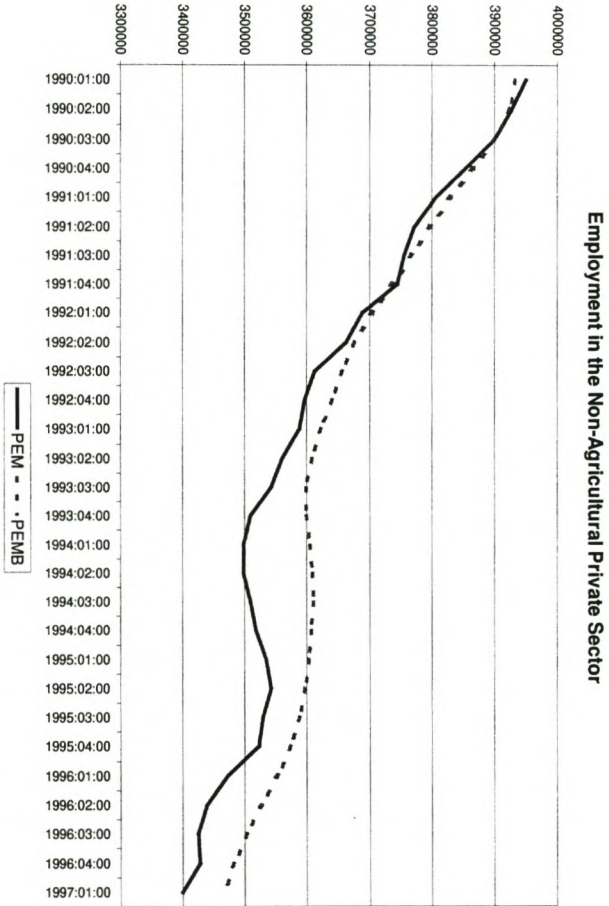
Real Sector





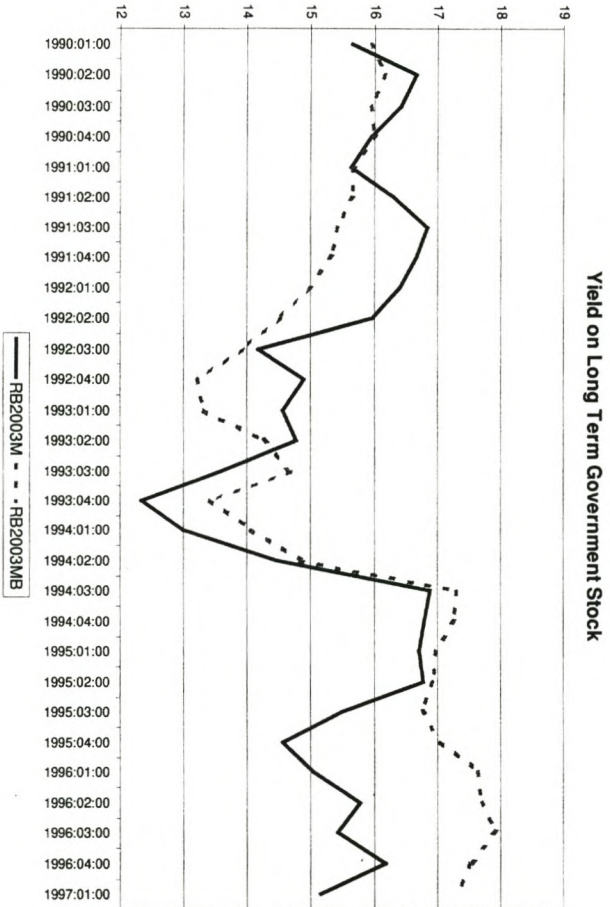
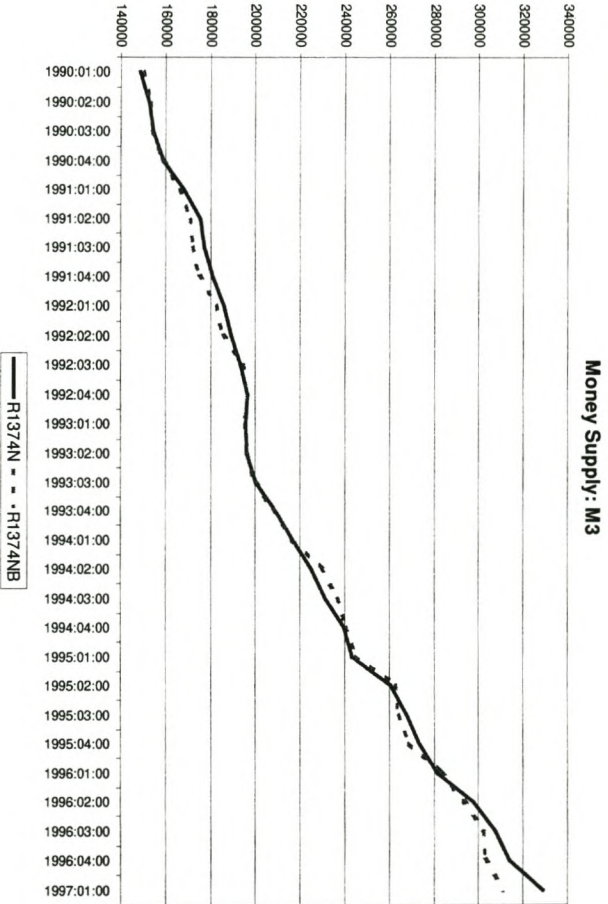


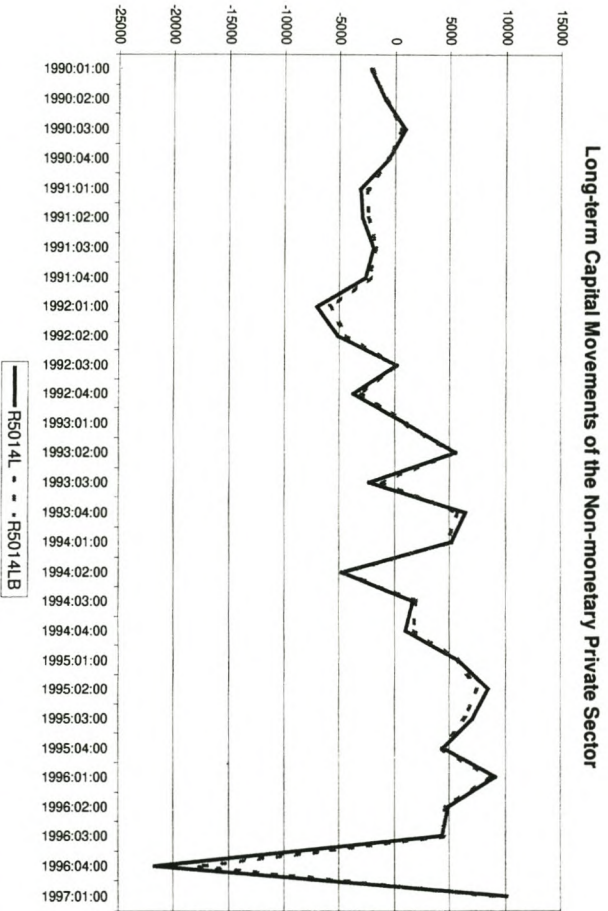
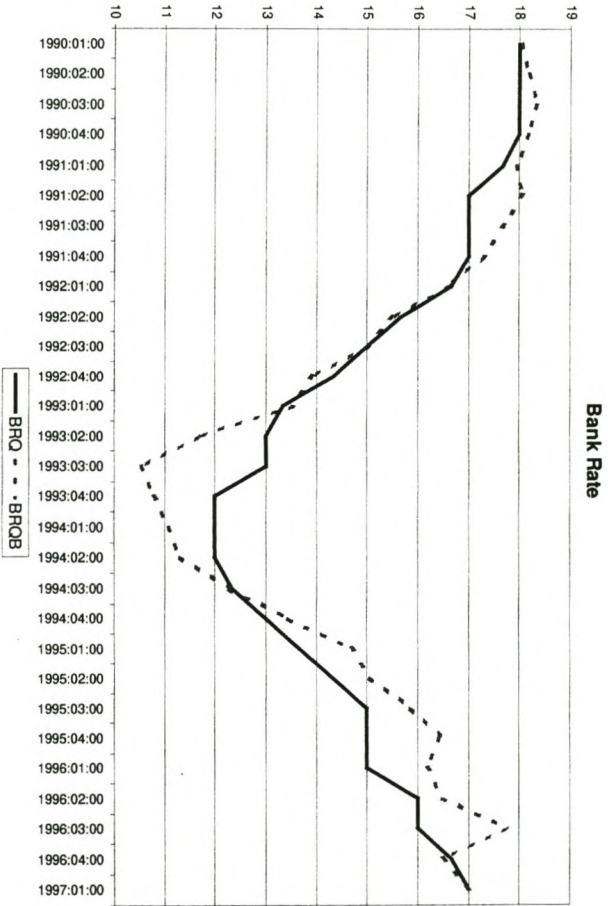
Employment and Wages



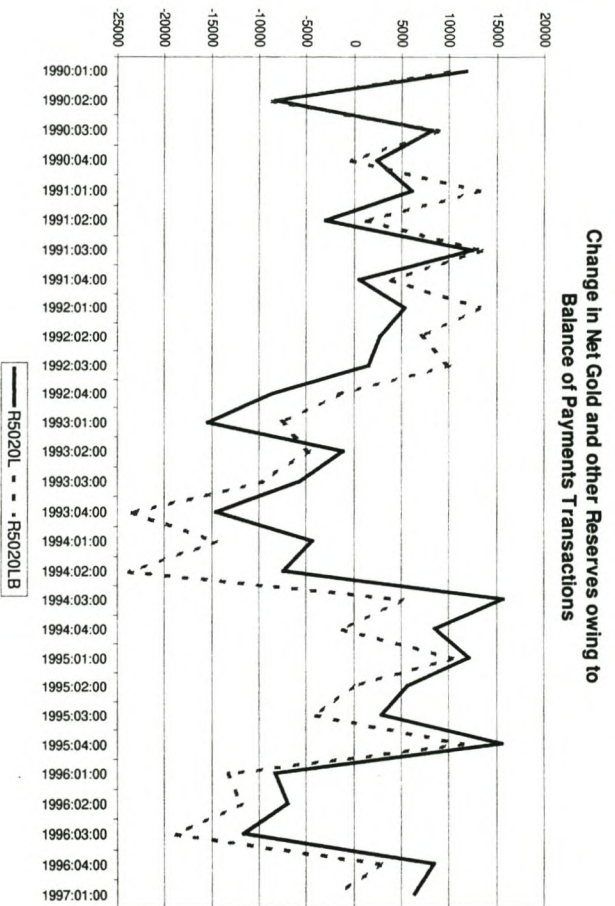


Financial Sector and the Capital Account of the Balance of Payments

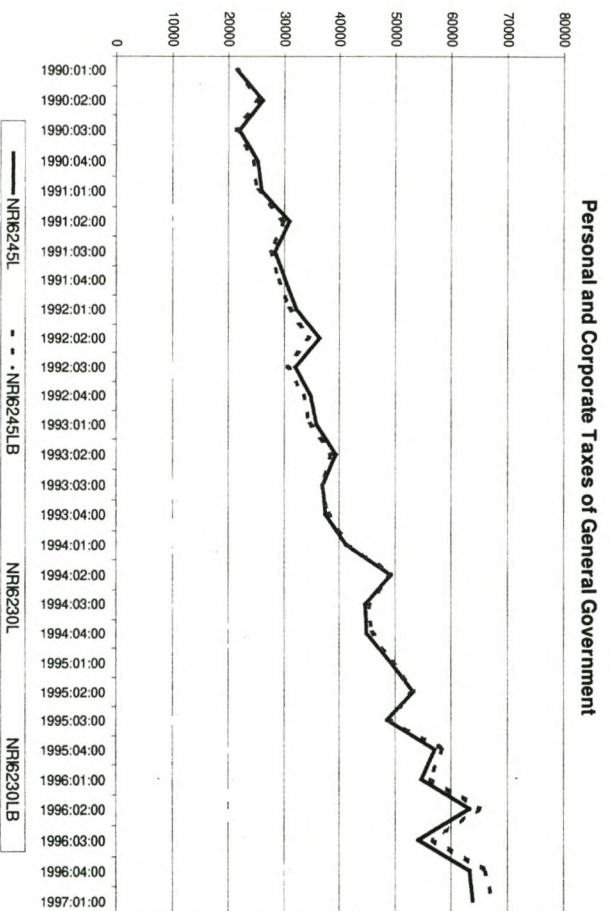


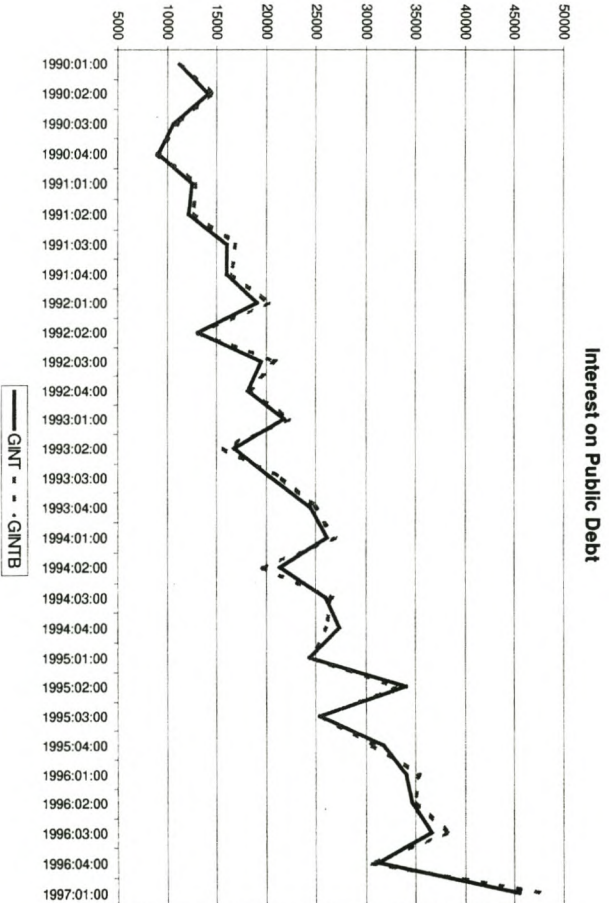
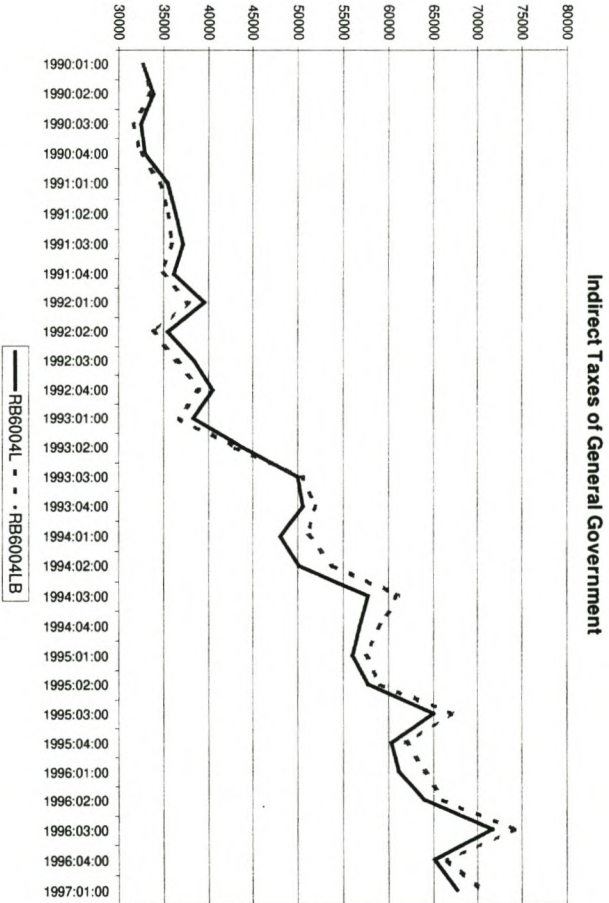




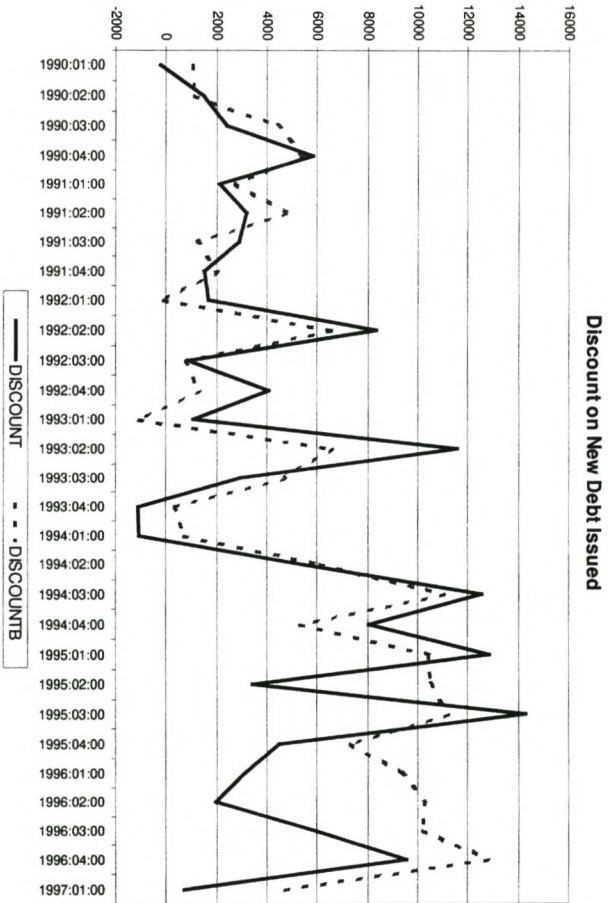


## Government Sector

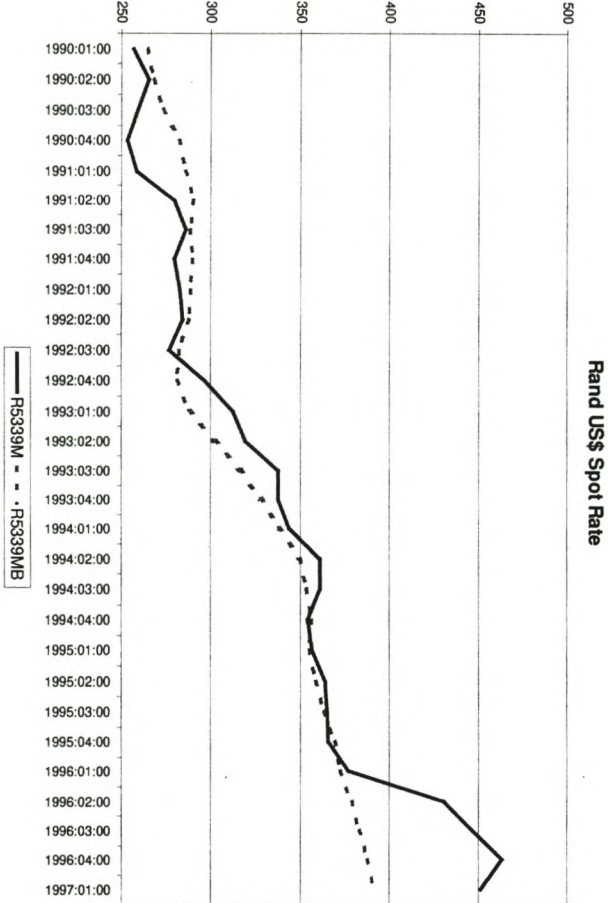


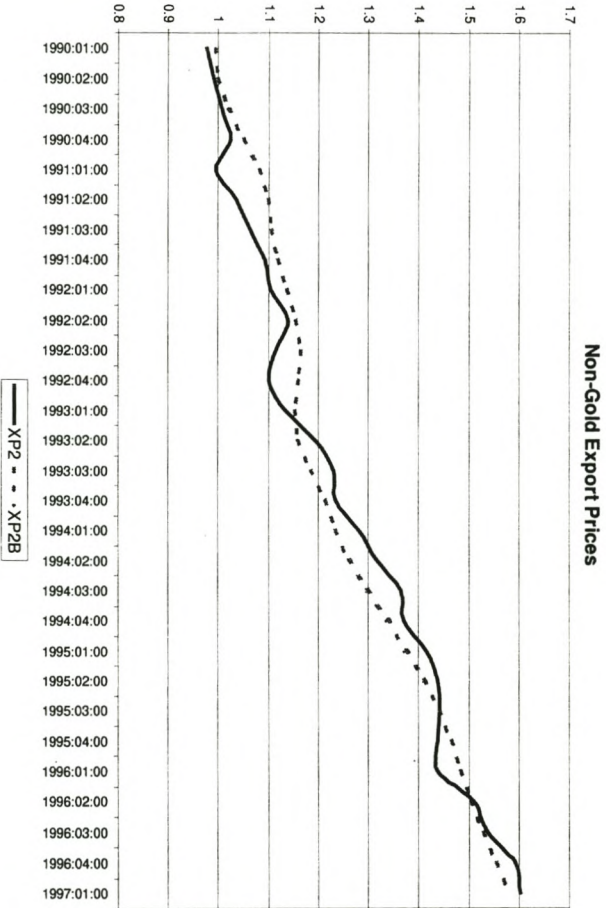
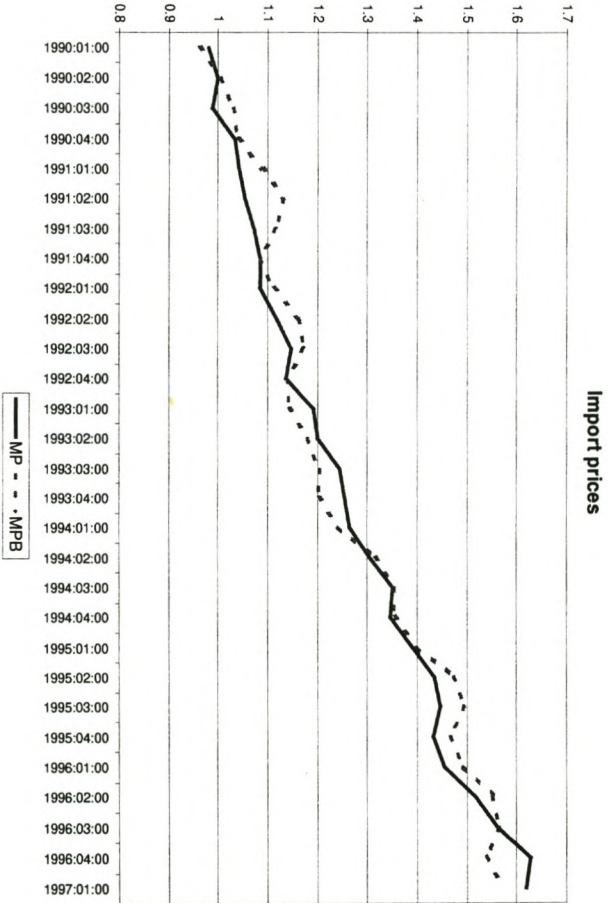




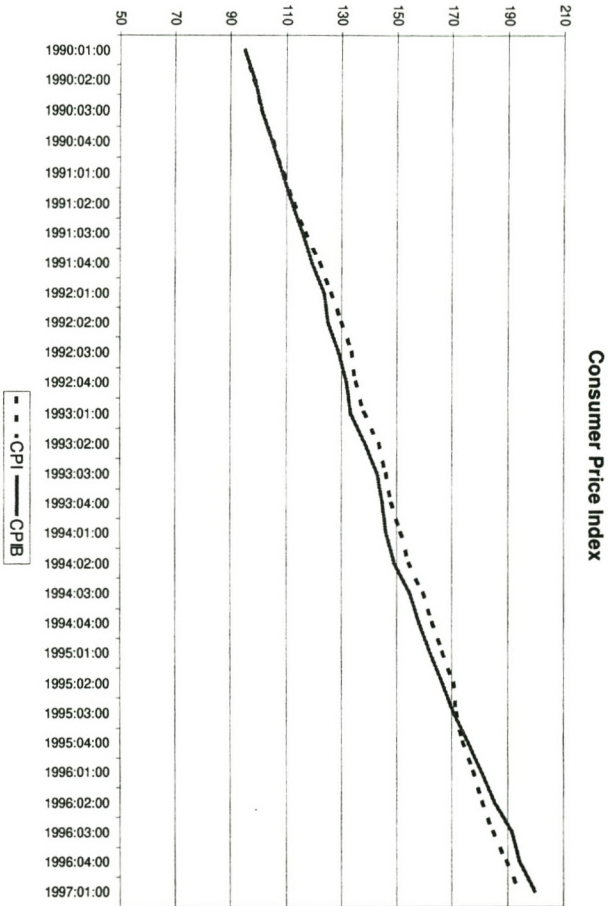


Prices









## **CHAPTER VIII: RESULTS OF DIFFERENT POLICY SIMULATIONS**

### **8.1. INTRODUCTION**

This chapter provides simulation results carried out with this study's macroeconomic model. A total of 6 simulations were carried out which include fiscal, monetary as well as exchange rate shocks or policy changes. The results are presented in summary tables with relevant explanations. Simulation results of alternative studies are also provided for comparison.

As outlined in Chapter II, a distinction is necessary when simulating policies under RATEX depending on whether the policy is anticipated or not. To measure the unique impact an anticipated policy has relative to an unanticipated one, a monetary policy simulation was carried out under both assumptions.

The following section briefly focuses on the treatment of anticipated versus unanticipated expectations in the simulations. Section 8.3. represents the simulation results and major findings.

### **8.2. ANTICIPATED AND UNANTICIPATED POLICY SIMULATIONS**

A change in the Bank rate can be considered as anticipated if the reaction function or expectation process would have predicted the change. If a policy is anticipated, the reaction function explaining the Bank rate remains therefore endogenous and the policy change is induced with a change to the add factor of



the reaction function. The same add factors are included in the relevant expectations processes.

Under an unanticipated policy, the reaction function is excluded for the simulation period during which the policy prevails. Monetary policy therefore becomes exogenous. Similar to anticipated policies, the reaction function will be reintroduced as a behavioural equation as soon as conventional monetary policy is once again reinstated. The expectation process remains in the model throughout. There will therefore be a divergence of actual and expected interest rates during the simulation of exogenous monetary policy<sup>1</sup>.

### **8.3. POLICY SIMULATIONS AND COMPARATIVE RESULTS**

In total, 6 policy simulations were carried out. These include exogenous shocks of fiscal policy, exchange rate depreciation and Bank rate changes either in isolation or part of a combination of an exchange rate shock and a responding Bank rate shock. Monetary policy was either assumed as unanticipated or anticipated. A policy simulation was also carried out to assess the unique impact of an anticipated vis a vis an unanticipated monetary policy response. All results are reported as deviations, either actual or in percentage form, from the base run simulation. The simulation period stretched over 6 years.

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<sup>1</sup>. Monetary policy is seen as exogenous as the reaction function is not determining the Bank rate. The exogenous monetary policy, could, however, be equivalent to the reaction functions solution. In this case, although exogenous, monetary policy would be anticipated as the reaction function could have generated the Bank rate simulation. Given, however, that unanticipated policy is simulated by means of an interest rate shock, this possibility is excluded from the current study.



### 8.3.1. SIMULATION 1: PERMANENT INCREASE OF GENERAL GOVERNMENT REAL CONSUMPTION SPENDING OF 1 PER CENT

This simulation evaluates the endogenous monetary policy response to a fiscal expansion. As the reaction function remains endogenous, the monetary policy response is anticipated. The 1 per cent increase in government consumption spending is assumed not to be accompanied by a tax increase but rather financed through the capital market. Table 7.1. provides the simulation results.

**Table 8.1. Permanent increase of general government real consumption spending of 1 per cent financed by capital market funding (Deviations from base run simulation)**

	1	2	3	4	5	6
Real GDP (% deviation)	0.22	0.24	0.07	-0.11	-0.06	0.12
Real PCE (% deviation)	0.06	0.14	-0.03	-0.28	-0.33	-0.18
Export of goods and non-factor services (% deviation)	0.02	0.09	0.04	-0.06	-0.04	0.03
Imports of goods and non factor services (% deviation)	0.46	0.71	0.39	-0.02	-0.02	0.28
Gross domestic fixed investment (% deviation)	0.14	0.24	0.06	-0.21	-0.09	0.27
Balance of payments: Current account (deviation from level)	-244	-300	-105	41	0	-370
Long term capital movements of the non monetary private sector (deviation from level; R millions)	-1	-12	-30	0.5	13	23
CPI (deviation from inflation rate)	0.00	0.07	0.14	0.04	-0.12	-0.12
Employment in non-agricultural private sector (deviation from level)	2282	5787	4824	-352	-3460	-951
Employment in non-agricultural private sector (% deviation)	0.06	0.15	0.13	-0.01	-0.10	-0.03
R/\$ spot rate (deviation from level)	0.22	0.69	0.16	-0.62	-0.20	0.64
R/\$ spot rate (% deviation)	0.08	0.24	0.06	-0.20	-0.06	0.18
Bank Rate (deviation from level)	0.00	0.12	0.24	0.19	-0.02	-0.12
Long term interest rates (deviation from level)	0.00	0.02	0.02	-0.04	-0.09	-0.08
Government interest payments (deviation from level)	58	134	267	451	670	896
Discount on government debt (deviation from level)	110	101	108	87	376	546
Budget deficit of General Government as % of GDP	0.1	0.2	0.3	0.4	0.4	0.3
M3 money supply (% deviation)	-0.01	0.17	0.24	0.08	-0.27	-0.40



The following government multipliers (change in GDP as a ratio of change in total government expenditure) can be reported:

**Table 8.2. South African general government consumption multipliers**

Year	1	2	3	4	5	6
General Government Consumption Multiplier	1.1	1.2	0.4	-0.5	-0.3	0.6

For the first 2 years, the fiscal expansion has a positive multiplier effect. GDP increase by more than the increase in government spending. However, for the remaining four years, the GDP gain is less than the increase in government spending as a result of tighter monetary policy. Higher interest rates negatively affect interest rate sensitive demand such as private consumption expenditure. As a result of the initial increase in output, the level of investment is higher in the first three years.

Given that the tax ratios have remained unchanged, the government expansion is financed predominantly through borrowing. Under the assumption that offshore and money market (Treasury Bills) funding remain unchanged, government's demand on the domestic capital market increases. This causes an initial increase in long-term interest rates, which also increases the discount on government debt, given no change in the coupon rate. Government's interest payments also increase accordingly.

Inflationary pressure, accelerated money supply growth and a weakening exchange rate causes an increase in the Bank rate that contributes to the reversal of the expansionary policy of the first two years. As a result of this

tighter monetary policy, actual and expectations of inflationary pressures are reduced which leads to long term interest rates lower than in the base run for the outer three years.

Inflationary pressures develop as a result of a higher level of demand as reflected by a higher level of employment. A higher deficit per se is not causing inflation as it is financed in the capital market and does therefore not increase the money supply. The initial inflationary pressures cause a weakening in the exchange rate which positively affects export growth. However, higher interest rates reverse this process in the outer years. Increased demand raises imports, which worsen the current account in spite of the export gain.

For comparison, Table 7.2 provides simulation results of a fiscal shock for a number of European countries. The fiscal shock entailed an increase in government purchases of goods and services of 1 per cent of GDP for the entire simulation period with no tax responses. All simulations were carried out with the QUEST II model developed by the European Commission (Roeger and Veld 1997:37-50). All numbers refer to percentage differences from the base run and given that government spending increases by 1 per cent of GDP, the GDP simulation results can be interpreted as government multipliers.



**Table 8.3: Impact of fiscal policy on numerous European countries**

YEAR	1	2	3	4	5
<b>GERMANY</b>					
Total GDP %	0.48	0.16	0.06	0.01	-0.01
Employment %	0.16	0.09	0.05	0.04	0.04
Inflation	0.28	0.07	0.02	0.01	0
<b>UK</b>					
Total GDP %	0.61	0.23	0.11	0.05	0.02
Employment %	0.21	0.16	0.1	0.07	0.05
Inflation	0.41	0.11	0.03	0	0
<b>FRANCE</b>					
Total GDP %	0.57	0.18	0.06	0.02	0
Employment %	0.19	0.09	0.05	0.04	0.04
Inflation	0.39	0.09	0.02	0	-0.01
<b>ITALY</b>					
Total GDP %	0.63	0.19	0.04	-0.01	-0.03
Employment %	0.2	0.07	0.03	0.02	0.02
Inflation	0.43	0.13	0.03	0	0
<b>BELGIUM</b>					
Total GDP %	-0.03	-0.03	-0.03	-0.04	-0.05
Employment %	-0.01	-0.01	-0.01	-0.01	-0.02
Inflation	-0.01	-0.01	-0.01	-0.01	-0.02
<b>SPAIN</b>					
Total GDP %	0.61	0.23	0.08	0.03	0.01
Employment %	0.15	0.06	0.02	0.02	0.02
Inflation	0.28	0.11	0.04	0.01	0

As can be seen from Table 8.3, government expenditure multipliers differ significantly between European countries. While the multiplier was above 0.6 for 3 countries, it is negligible and even negative for Belgium. According to this study and in contrast to the current study's findings for South Africa, all countries have an initial government multiplier substantially below 1.

For South Africa, Smal (1995:14-15) utilised the SARB's model to carry out a simulation entailing a 10 per cent increase in nominal consumption spending of general government, excluding remuneration of employees. The reported simulation results suggest that the estimated government multiplier for South Africa is negligible. The following deviations from the base run simulation (actual and percentage differences) can be reported:

**Table 8.4: Impact of expansionary government consumption spending in South Africa- SARB Model**

Year	1	2	3	4	5
<b>GDP %</b>	0	0	0	-0.1	-0.1
<b>Inflation</b>	0.14	0.06	0.02	0.02	-0.01
<b>Deficit before borrowing</b>	1480	2060	2500	3270	3790

Whitley (1994: 140-143) presents government expenditure multipliers for 3 UK models. In contrast to the estimates provided for South Africa from the current study as well as the results for European states from the QUEST II model, these multipliers suggest a rather significant contribution of expansionary fiscal policy to medium term growth.

**Table 8.5: Full model government expenditure multipliers in 3 UK models**

Year	1	2	3	4	5
HM Treasury Model	0.99	1.06	1.12	1.11	1.02
NIESR Model	1.84	2.21	1.32	0.62	0.4
LBS Model	1.08	1.64	1.69	1.63	1.63



### 8.3.2. SIMULATION 2: AVERAGE INCREASE OF 1.5 PERCENTAGE POINTS IN THE BANK RATE FOR THE ENTIRE SIMULATION PERIOD

In this simulation, an increase to the add factor leads to an average increase in the Bank rate of 1.5 percentage points over the entire simulation period. However, for specific periods, the Bank rate deviates by more than 1.5 percentage points from the base run. The following simulation results can be reported:

**Table 8.6: Simulation results of an average increase of 1.5 percentage points in the Bank rate relative to base run (Deviations from base run simulation)**

	1	2	3	4	5	6
Real GDP (%deviation)	-0.43	-2.09	-3.61	-3.28	-1.51	-0.86
Real PCE (%deviation)	-0.56	-2.88	-5.46	-6.29	-5.17	-4.30
Export of goods and non-factor services (%deviation)	-0.11	-0.70	-1.68	-1.86	-1.06	-0.78
Imports of goods and non factor services (%deviation)	-0.63	-4.34	-8.31	-8.80	-6.37	-5.33
Gross domestic fixed investment (%deviation)	-0.47	-2.36	-4.08	-3.28	-0.31	1.21
Balance of payments: Current account (deviation from level)	176	1543	2310	2661	2939	2460
Long term capital movements of the non monetary private sector (deviation from level; R millions)	1	59	254	37	241	-200
CPI (deviation from inflation rate)	0.00	-0.16	-1.02	-2.00	-2.10	-0.99
Employment in non-agricultural private sector (deviation from level)	-2481	-26754	-68918	-91931	-65197	-23711
Employment in non-agricultural private sector (% deviation)	-0.06	-0.71	-1.88	-2.55	-1.81	-0.66
R/\$ spot rate (deviation from level)	-2.05	-9.41	-19.08	-22.01	-20.00	-23.81
R/\$ spot rate (%deviation)	-0.75	-3.26	-6.69	-7.14	-5.72	-6.58

<b>Bank Rate (deviation from level)</b>	1.05	2.22	2.09	0.96	0.49	1.92
<b>Long term interest rates (deviation from level)</b>	-0.01	-0.24	-0.72	-1.05	-1.05	-0.83
<b>Government interest payments (deviation from level)</b>	96	550	1170	1823	2576	3460
<b>Discount on government debt (deviation from level)</b>	191	231	-652	-1259	362	1077
<b>Budget deficit of General Government as % of GDP</b>	0.2	1.2	2.2	2.6	2.2	2.1
<b>M3 money supply (%deviation)</b>	-0.02	-0.76	-3.31	-7.06	-9.56	-8.99

The reaction function of the Bank rate remains endogenous throughout and the expectations processes are adjusted by the same add factor as the reaction function. This is therefore a fully anticipated policy.

A tighter monetary policy reduces output and thus employment. Private consumption is lower for the entire simulation period. Gross domestic fixed investment is below the base run except for the final year of simulation. Lower long-term interest rates throughout (as discussed below) as well as GDP gradually approaching base run levels cause this acceleration in investment in the final year.

The average increase of 1.5 percentage points in the Bank rate causes substantial increases in the real Bank rate, particularly in year 3 and 4. For those years, the real Bank rate is 3 percentage points higher than in the base run simulation.

Inflation and money supply growth are below base run for the entire simulation period. Lower demand, increased unemployment and thus lower real wage claims and unit labour costs lead to lower inflation. A lower level of GDP and its components as well as higher short-term rates reduce the demand for credit and thus the money supply. These developments, together with an appreciating



exchange rate, place downward pressure on the Bank rate as can be seen in year 3, 4 and 5 of the simulation.

Higher short-term interest rates and resulting lower inflation lead to an overall appreciation of the spot as well as real effective exchange rate, which negatively affects exports. In spite of the appreciation, imports are also falling. The income effect of a tighter monetary policy therefore outweighs the substitution effect of such a policy. The current account as a whole is improving, which suggests that the domestic demand adjustment also outweighs the negative price effect the appreciation has on exports. Tighter monetary policy proves therefore successful in improving the current account via its impact on domestic demand.

Long-term interest rates are lower than in the base run simulation. Tighter monetary policy, lower output and lower prevailing inflation has a positive impact on inflationary expectations. Also, the improvement in the current account and a higher level of net capital inflows improves liquidity in the capital market. This results in an overall lower level of long-term interest rates.

Lower long-term interest rates lower the cost of new funding from the capital market. However, this is partly counteracted by the increase in the Bank rate and thus money market rates. The primary reason why government interest payments increase is the lower level of tax revenue and thus the higher funding requirement that government faces. The tighter monetary policy causes both, a decline in real activity and inflation. Both of these aspects negatively affect the tax base.

De Jager (1998) utilised the SARB's econometric model to carry out a policy simulation involving the Bank rate. The policy was a sustained 10 per cent (approximately 0.5 percentage points) increase in the Bank rate. The following deviations (as a percentage of the base run or actual) can be reported:

**Table 8.7. Impact of a 10 per cent rise (approx. 1.5 percentage points) in the Bank rate in South Africa-SARB Model**

Year	1	2	3	4	5
<b>GDP %</b>	-0.2	-0.6	-0.8	-0.9	-1.1
<b>Inflation</b>	-0.13	-0.34	-0.42	-0.51	-0.61
<b>Balance on current account</b>	275	1025	1450	1925	2375
<b>Government deficit before borrowing</b>	575	1775	2975	4400	6800
<b>Total money supply (M3)</b>	-0.9	-1.8	-2.7	-3.5	-4.6

These results indicate that according to the SARB model, monetary policy has a substantial impact on real economic activity. These results therefore support the findings of this study's simulations.

Using the annual model of the Bureau of Economic research, Smit (1997) carried out a policy simulation that entailed a 3 percentage point cut in the real Bank rate for the entire simulation period. The following results can be reported:



**Table 8.8: Impact of a Bank rate cut in South Africa-BER annual model**

Year	1	2	3	4
<b>GDP(deviation from growth rate)</b>	0.1	0.3	0.6	0.6
<b>Current account (derivation from level as % of GDP)</b>	0	-0.3	-0.6	-1.1
<b>PPI ( deviation from inflation rate)</b>	0.1	0	0.2	0.2
<b>Exchange rate (deviation from % depreciation)</b>	0.8	0.2	0.5	0.7

Turner, Richardson and Raufflet (1996) used the OECD's INTERLINK world model to simulate the impact of a 1 percentage point cut in nominal short and long term interest rates on the 7 major OECD economies. The following results can be reported for some of these economies<sup>2</sup>. All statistics refer to percentage deviations from baseline.

**Table 8.9: Impact of a 1 percentage point cut in nominal short and long term interest rates on OECD economies - OECD INTERLINK World Model**

YEAR	1	2	3	4	5
<b>UNITED STATES</b>					
<b>Real GDP level</b>	0.22	0.49	0.59	0.57	0.56
<b>Inflation rate</b>	0.09	0.22	0.45	0.69	0.85
<b>Unemployment rate</b>	-0.09	-0.25	-0.34	-0.36	-0.34
<b>JAPAN</b>					
<b>Real GDP level</b>	0.12	0.41	0.62	0.70	0.72
<b>Inflation rate</b>	0.08	0.38	0.79	1.06	1.18
<b>Unemployment rate</b>	-0.01	-0.03	-0.05	-0.07	-0.08
<b>GERMANY</b>					
<b>Real GDP level</b>	0.28	0.52	0.63	0.71	0.76
<b>Inflation rate</b>	0.11	0.15	0.23	0.35	0.47
<b>Unemployment rate</b>	-0.07	-0.19	-0.27	-0.33	-0.37
<b>UNITED KINGDOM</b>					

<sup>2</sup>. Only the first 5 years of the policy simulation are reproduced. The actual simulation period was 10 years.



<b>Real GDP level</b>	0.23	0.50	0.61	0.70	0.83
<b>Inflation rate</b>	0.33	0.86	0.98	0.82	0.57
<b>Unemployment rate</b>	-0.04	-0.15	-0.25	-0.33	-0.39

### 8.3.3. SIMULATION 3: AN ANTICIPATED AS WELL AS UNANTICIPATED INCREASE IN THE BANK RATE OF 5 PERCENTAGE POINTS FOR THE FIRST YEAR

In the case of unanticipated monetary policy, the reaction function of the Bank rate is excluded for the first year in which the interest rate increase occurs after which it will be reintroduced. Expectations gradually converge to the Bank rate, particularly once the reaction function is reintroduced in model simulation. However, initially, this policy change is not anticipated and a divergence prevails between actual and expected Bank rate. Table 7.9. provides the simulation results of the unanticipated increase relative to the base run.

**Table 8.10: Simulation results of an unanticipated increase in the Bank rate of 5 percentage points for the first year (Deviations from base run simulation)**

	1	2	3	4	5	6
<b>Real GDP (%deviation)</b>	-1.76	-5.34	-4.46	0.87	3.16	-0.06
<b>Real PCE (%deviation)</b>	-2.39	-7.69	-8.17	-2.75	1.78	0.13
<b>Export of goods and non-factor services (%deviation)</b>	-0.23	-1.83	-2.46	-0.25	1.25	0.24
<b>Imports of goods and non factor services (%deviation)</b>	-2.82	-12.27	-12.39	-1.88	4.59	-0.17
<b>Gross domestic fixed investment (%deviation)</b>	-1.32	-5.69	-4.76	3.73	7.40	1.45
<b>Balance of payments: Current account (deviation from level)</b>	1208	4721	3119	-1516	-5809	842
<b>Long term capital movements of the non monetary private sector (deviation from level; R millions)</b>	2	150	514	109	45	-343
<b>CPI (deviation from inflation rate)</b>	0.02	-0.45	-2.63	-2.78	0.50	3.47
<b>Employment in non-agricultural private sector (deviation from level)</b>	-11575	-84673	-136707	-68080	50951	64184
<b>Employment in non-agricultural private sector (% deviation)</b>	-0.30	-2.24	-3.72	-1.89	1.41	1.79



<b>R/\$ spot rate (deviation from level)</b>	-4.43	-20.33	-22.51	-2.41	4.51	-11.91
<b>R/\$ spot rate (%deviation)</b>	-1.63	-7.04	-7.89	-0.78	1.29	-3.29
<b>Bank Rate (deviation from level)</b>	4.80	3.62	-0.57	-3.06	-0.18	4.41
<b>Long term interest rates (deviation from level)</b>	-0.09	-0.79	-1.59	-1.12	0.28	0.76
<b>Government interest payments (deviation from level)</b>	385	1442	2075	2013	1746	2545
<b>Discount on government debt (deviation from level)</b>	670	257	-1960	-1631	-345	2897
<b>Budget deficit of General Government as % of GDP</b>	0.9	3.1	3.3	1.1	-0.3	-0.9
<b>M3 money supply (%deviation)</b>	0.07	-2.39	-7.36	-9.71	-5.00	1.04

Even though only induced for the first years, an unanticipated monetary policy shock equals a substantial increase in the Bank rate for the first 2 years. Given the assumption of consistent monetary policy as reflected by the reaction function, this shock is then counteracted in the following three years based on more favourable inflation and money/credit statistics as well as a real exchange rate appreciation.

This policy causes a substantial contraction in the real sector for the first three years before the lower Bank rate reverses the process in the outer years. Monetary policy in the outer years is partly counteracting the initial tight exogenous policy response. This causes the real and financial sector to reflect dynamics substantially different to the base run. Therefore, the initially tight monetary policy makes the base run simulation less suitable for comparison.

The magnitude of this policy impact on the real and financial sector shows the effectiveness of monetary policy to re-establish balance rather quickly should excess demand prevail in the economy. However, the GDP and employment contraction shows that the cost to reduce inflation and improve the current account with a once off tighter monetary policy are rather sizeable.



Government interest payments increase sizeably which is again due to the negative effect tighter monetary policy has on the tax base. Personal and corporate direct taxes are on average 3.2 per cent and 10.5 per cent respectively lower than under the base run simulation. For indirect taxes, the decline amounts to 5.4 per cent.

The same simulation was also carried under the assumption of policy anticipation. The purpose is to assess the difference in the effectiveness of monetary policy if the Bank rate change is anticipated relative to an unanticipated policy response. The 5 percentage points increase is incorporated by means of an add factor. As before, the same add factor was added to the relevant expectations processes. Table 7.10 provides the differences for the first year.

**Table 8.11: Simulation results of an anticipated increase in the Bank rate of 5 percentage points (Deviations from the simulation of the unanticipated Bank rate increase)**

	Q1	Q2	Q3	Q4	Avg.
Real GDP (%deviation)	-0.003	-0.46	-0.41	-0.37	-0.311
Real PCE (%deviation)	-0.005	-0.47	-0.49	-0.47	-0.357
Export of goods and non-factor services (%deviation)	0.000	-0.23	-0.31	-0.31	-0.212
Imports of goods and non factor services (%deviation)	-0.003	-0.36	-0.77	-1.00	-0.532
Gross domestic fixed investment (%deviation)	-0.001	-0.85	-0.78	-0.69	-0.581
Balance of payments: Current account (deviation from level)	1.327	-281	53	202	-6
Long term capital movements of the non monetary private sector (deviation from level; R millions)	0.1	5	-3	2	1
CPI (deviation from inflation rate)	0.000	0.00	0.00	-0.02	-0.004
Employment in non-agricultural private sector (deviation from level)	-7.000	-766	-3229	-6256	-2565
Employment in non-agricultural private sector (% deviation)	0.000	-0.02	-0.08	-0.16	-0.065



<b>R/\$ spot rate (deviation from level)</b>	0.000	-5.49	-3.66	-2.84	-2.998
<b>R/\$ spot rate (%deviation)</b>	0.000	-2.05	-1.37	-1.04	-1.132
<b>Bank Rate (deviation from level)</b>	0.056	-0.69	0.08	0.04	-0.129
<b>Long term interest rates (deviation from level)</b>	0.000	0.01	0.00	-0.03	-0.004
<b>Government interest payments (deviation from level)</b>	1.860	83	82	62	57
<b>Discount on government debt (deviation from level)</b>	1.154	62	188	189	110
<b>Budget deficit of General Government as % of GDP</b>	0	0.3	0.3	0.2	0.2
<b>M3 money supply (%deviation)</b>	0.000	-0.07	-0.10	-0.22	-0.098

Higher interest rates cause an appreciation of the exchange rate. When monetary policy is anticipated, the exchange rate responds with a greater magnitude although it is gradually converging to the unanticipated level. This shows the forward-looking nature of the exchange rate.

Spending patterns adjust sooner in the case of an anticipated policy. As a result, private consumption spending and imports decline more relative to the unanticipated case. This results in an overall sharper decline in GDP and employment, which is enforced by lower exports from the exchange rate impact.

Overall, the result confirms that the real and financial variables respond more effectively in the case when the Bank rate increase is anticipated, which is in line with forward-looking behaviour. This allows a loosening of monetary policy already in 1999 relative to the unanticipated case. The Bank rate itself is on average lower for 1999 than under the exogenous case. A desired monetary policy response is therefore easier accomplished with an anticipated policy as monetary policy is more effective.

#### 8.3.4. SIMULATION 4: AVERAGE DEPRECIATION OF THE RAND/US\$ SPOT RATE OF 10 PER CENT

Similar to the fiscal policy simulation, the purpose of this simulation lies in assessing the endogenous monetary policy response to an exogenous shock. The exchange rate is an explanatory variable in the reaction function of the SARB so that there is a direct monetary policy response. Given inflationary consequences, there is also an indirect effect.

To keep the exchange rate equation endogenous, the policy effect was incorporated with a constant add factor. The average depreciation of the exchange rate for the entire simulation period amounted to 10 per cent relative to the base run. Table 7.11. provides the simulation results.

**Table 8.12: Simulation results of an average depreciation of the rand/US\$ spot rate of 10 per cent for the entire simulation period (Deviations from base run simulation)**

	1	2	3	4	5	6
Real GDP (%deviation)	0.82	1.45	0.44	-1.05	-1.13	0.34
Real PCE (%deviation)	0.52	1.40	1.08	-0.35	-0.86	0.44
Export of goods and non-factor services (%deviation)	1.78	1.76	1.39	0.51	0.00	0.63
Imports of goods and non factor services (%deviation)	0.41	0.38	0.18	-2.52	-2.75	-0.19
Gross domestic fixed investment (%deviation)	0.44	0.96	-0.79	-3.71	-3.75	-0.91
Balance of payments: Current account (deviation from level)	2657	3710	4600	5394	5055	2407
Long term capital movements of the non monetary private sector (deviation from level; R millions)	-16	-279	-548	37	119	511
CPI (deviation from inflation rate)	0.21	2.15	2.33	1.28	-0.24	-0.85
Employment in non-agricultural private sector (deviation from level)	7375	28207	29214	-4415	-33077	-19815
Employment in non-agricultural private sector (% deviation)	0.19	0.75	0.80	-0.12	-0.92	-0.55



<b>R/\$ spot rate (deviation from level)</b>	32.04	35.39	33.24	24.51	25.48	37.15
<b>R/\$ spot rate (%deviation)</b>	11.76	12.25	11.65	7.95	7.29	10.27
<b>Bank Rate (deviation from level)</b>	0.24	1.39	2.75	3.16	1.98	0.97
<b>Long term interest rates (deviation from level)</b>	-0.09	0.42	0.50	0.12	-0.33	-0.30
<b>Government interest payments (deviation from level)</b>	-241	-542	-568	-387	-323	-749
<b>Discount on government debt (deviation from level)</b>	-556	-110	478	279	-415	-1484
<b>Budget deficit of General Government as % of GDP</b>	-0.7	-1.1	-0.9	-0.3	-0.1	-0.8
<b>M3 money supply (%deviation)</b>	1.65	5.74	9.88	11.89	10.52	9.83

The depreciation causes an increase in inflation for the first 4 years of the simulation after which inflation runs slightly below base run. The average real effective exchange rate depreciation over the 6 years amounts to 6.1 per cent.

Exports are continuously above base run, particularly in the first 3 years when the real effective exchange rate depreciates on average by 8.9 per cent relative to 3.4 per cent for the remaining three years. In spite of lower inflation in the outer 2 years, the real exchange rate depreciation is less on average, which is due to the lower spot depreciation in the outer three years.

The initial increase in GDP causes imports to rise above base run levels for the first 3 years after which they are persistently below. This shows again that domestic economic activity is the dominant determinant of imports rather than price competitiveness of imports. However, the current account shows an improvement for the entire simulation due to a higher level of exports. An exchange rate depreciation will therefore, improve the current account even if this is only achieved in conjunction with higher short term interest rates.

Money market rates are persistently higher while long-term interest rates are only higher for the intermediary years. Nevertheless, for the entire simulation period, government's interest payments are below base run. The reason for the lower debt costs lie with higher revenue earnings as a result of a higher nominal growth.

Smal (1996: 35-38) used the SARB econometric model to carry out a 20 per cent depreciation of the nominal rand/US\$ spot rate with a tightening in monetary and fiscal policy as well as moderate wage claims<sup>3</sup>. The following differences (percentage points and actual) between the base and integrated simulation can be reported.

**Table 8.13: The impact of a 20 per cent nominal depreciation in South Africa – SARB Model**

Year	1	2	3	4	5
GDP growth rate (%)	1	0.2	0.1	0.1	0.1
Inflation (%)	2.3	1	0.2	-0.7	-1.5
Balance on the current account	9160	10720	11400	11700	10980

Smit carried out an exchange rate simulation where the R/\$ spot rate depreciated by 10 per cent in the first year and a further 6 per cent every year thereafter. The Bank rate is endogenous in this simulation. The following results can be reported:

<sup>3</sup>. The simulation period spread from 1990 to 1994. The average inflation for that period was 12.5 per cent.



**Table 8.14: Impact of currency depreciation with endogenous Bank rate in South Africa - BER annual model**

<b>Year</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
<b>GDP (deviation from growth rate)</b>	0.8	1	0.8	0.4
<b>Current account (derivation as % of GDP)</b>	0.6	0.9	0.5	-0.3
<b>PPI (deviation from inflation rate)</b>	1.1	0.6	0	-0.2
<b>Exchange rate (deviation from % depreciation)</b>	10	2.1	-1.7	-1.9
<b>Nominal Bank rate (derivations from level)</b>	0.05	-0.6	-1.06	-0.6

### **8.3.5. SIMULATION 5: INITIAL DEPRECIATION OF 20 PER CENT OF THE RAND/US\$ SPOT RATE AND A CORRESPONDING INCREASE IN THE BANK RATE OF 5 PER CENT FOR THREE QUARTERS**

This simulation is the combination of an exchange rate shock and an initial unanticipated response by the SARB. The exchange rate is depreciated by 20 per cent in the first quarter of the simulation with the help of a negative add factor while the exogenous monetary policy response last for the first three quarters. After the three quarters, the policy reaction is expected to be anticipated. The reaction function is therefore excluded from the simulation for the first nine months after which it will be endogenised. The following results can be reported:

**Table 8.15: Simulation results of an initial depreciation of 20 per cent of the rand/US\$ spot rate and a corresponding increase in the Bank Rate of 5 per cent (Deviations from base run simulation)**

	1	2	3	4	5	6
Real GDP (%deviation)	-0.85	-3.92	-3.73	0.43	2.57	0.36
Real PCE (%deviation)	-1.69	-5.62	-5.98	-2.00	1.81	0.95
Export of goods and non-factor services (%deviation)	1.42	-1.67	-2.06	-0.32	0.89	0.33
Imports of goods and non factor services (%deviation)	-2.28	-10.36	-8.89	-1.76	4.07	1.11
Gross domestic fixed investment (%deviation)	-0.79	-4.42	-4.70	1.85	5.66	1.61
Balance of payments: Current account (deviation from level)	3393	5008	2475	-884	-5003	-677
Long term capital movements of the non monetary private sector (deviation from level; R millions)	-22	-87	321	182	85	-165
CPI (deviation from inflation rate)	0.33	1.34	-2.42	-2.54	0.05	2.44
Employment in non-agricultural private sector (deviation from level)	-1940	-56045	-104623	-60291	36363	56731
Employment in non-agricultural private sector (% deviation)	-0.05	-1.48	-2.85	-1.67	1.01	1.58
R/\$ spot rate (deviation from level)	22.61	-13.96	-15.56	-1.43	4.93	-6.10
R/\$ spot rate (%deviation)	8.30	-4.83	-5.45	-0.46	1.41	-1.69
Bank Rate (deviation from level)	4.62	3.41	0.10	-2.08	-0.24	3.35
Long term interest rates (deviation from level)	-0.14	-0.24	-1.22	-0.96	0.14	0.62
Government interest payments (deviation from level)	121	1026	1546	1489	1174	1572
Discount on government debt (deviation from level)	203	699	-1430	-1386	-604	1610
Budget deficit of General Government as % of GDP	0.1	2.2	2.3	0.8	-0.4	0.3
M3 money supply (%deviation)	1.99	1.47	-2.57	-5.28	-2.15	2.57

The initial depreciation and interest rate increases cause a contraction in the economy. With the exchange rate appreciating sharply above base run in year 2 and 3, the real sector contraction intensifies as exports run below base run due to loss of price competitiveness. The tighter monetary policy also causes substantial contractions in private consumption expenditure and gross domestic fixed investment.



Interest rates remain above base run for the first three years before being lower than in the base run simulation. As was the case with the previous sharp monetary policy tightening (simulation 3), the proceeded endogenous policy compensates for the initial policy, given its effect on the economy.

The tight monetary policy response causes a reversal of the depreciation from the second year onwards. The exchange rate over and undershoot the base run simulations but the amplitudes gradually narrow so that the initial exogenous and pursued endogenous monetary policy response as well as adjustments in the economy do initiate gradual convergence to the base run exchange rate level.

#### **8.4. CONCLUSION**

Simulating monetary policy under weak RATEX necessitates the distinction between anticipated and unanticipated policies in order to reconcile induced changes to the reaction function with the corresponding expectations process. An anticipated policy shock implies a similar accommodation in the expectations process as it does for the reaction function of the SARB. In the unanticipated case, discrepancies occur, as the expectations process is not altered with the new policy.

Policy simulations show that expansionary fiscal policy through accelerated spending has only limited effect on the real economy. A positive multiplier effect prevails only for the first 2 years after which tighter interest rates lead to crowding out of private interest rate sensitive demand.

An average bias towards more restrictive monetary policy is successful in reducing inflation in South Africa but the potential cost to the real sector are rather high. In spite of higher average short-term interest rates, long-term interest rates are positively affected as inflationary fears are curtailed. Investment, which is driven by long term interest rates rather than short rates, is therefore primarily affected by the lower demand in the economy. The effectiveness of monetary policy can be improved further if the policy change is anticipated.

An exchange rate shock accompanied by a temporarily excessive monetary policy shock causes a sizeable contraction in the real sector initially. However, this creates the foundation for a higher output level in the medium term as it allows lower average short-term interest rates. An excessive monetary policy response will, however, lead to sizeable real appreciation following the initial shock, which is counterproductive to export growth. The current account nevertheless improves on the back of falling domestic demand.

A sustained weakness of the exchange rate has limited impact on growth in the medium term as it leads to higher average short term interest rates over the entire simulation period. However, the current account improves, primarily due to higher export growth. but also a slowdown in import growth.



## **CHAPTER IX: CONCLUSIONS AND FURTHER RESEARCH**

### **9.1. INTRODUCTION**

This study addresses the Lucas critique for monetary policy simulations through the application of weak RATEX in a macroeconometric model (Chapter II). While numerous studies have relied on fully model consistent expectations, the empirical difficulties as well as strict assumption requirements, do suggest that a weaker definition of RATEX proves more appropriate (Chapter III and VI). This is particularly the case for South Africa where monetary policy can be modelled with a policy reaction function upon which expectations are formed (Chapter V). Chapters VI and VII focus on the specification, estimation and testing of a macroeconometric model for South Africa while Chapter VIII provides simulation results of the model with numerous policy scenarios.

It is the aim of this Chapter to summarise the main findings of the study. These refer to the theoretical application of the RATEX methodology as well as the main simulation results of monetary policy in South Africa. Suggestions for further research will also be provided.

### **9.2. MAIN CONCLUSIONS**

#### **9.2.1. RATEX METHODOLOGY AND APPLICATION FOR SOUTH AFRICA**

The Lucas critique, questioning the usefulness of structural econometric models for policy analysis, has generated numerous responses. While atheoretical analysis like VAR models have received increased attention, the use of a

structural model has remained entrenched in mainstream econometrics. To address the Lucas critique, these models were modified to include RATEX.

Several interpretations have been given to RATEX in practical econometrics. Numerous models have adopted the strong version, associating RATEX will fully model consistent expectations. This approach has numerous difficulties, including the determination of a stable solution, the choice of terminal conditions, the difficulty of forecasting with such models and the strict information assumptions required. The latter point is of particular relevance in large-scale models.

If policy is transparent and consistent, an alternative approach is provided for addressing the Lucas critique, weak RATEX. Consistent policy implies the ability to model such a policy through a reaction function, reflecting the policy stance through a structural model. In South Africa, the SARB has been following such a policy since the introduction of the recommendations of the De Kock Commission. This allows the Lucas critique to monetary policy to be addressed through the structural inclusion of an expectation process based on the reaction function of the SARB.

As is the case with strong RATEX, policy simulations with weak RATEX necessitate the distinction between anticipated and unanticipated policies. In the case of an anticipated policy, the accommodation of the policy shock in the reaction function is identical for the expectation process. With the unanticipated policy, this is not the case, allowing a deviation between expectations and policy responses based on the induced change in the reaction function.



### 9.2.2. SIMULATION RESULTS

The policy simulations show that expansionary fiscal policy is only of limited effect as positive multiplier effects only prevail in the initial phase of expansionary government spending. This is confirmed for South Africa by alternative studies while evidence for other countries, particularly Europe, is also supporting this notion.

An average tightening bias in monetary policy, as reflected by an average increase in the Bank rate, is successful in curtailing inflation but the effects on the real sector are rather harsh. Monetary policy influences inflationary pressures through the impact of interest rates on domestic demand and the exchange rate while the impact of demand conditions on wage pressures appear to be limited in the South African case.

The simulations results suggest that in order not to impose excessive hardship on the real sector, the successful curtailment of inflation in South Africa has to be a co-ordinated policy attempt, a vision that is gaining shape with the possible introduction of inflation targeting. Placing the entire emphasis on monetary policy and thus to a large extent on the demand side of the economy is not conducive to sustained growth prospects. The South African economy is supply constraint in the sense that an economic recovery is generally associated with a worsening in the current account. Addressing inflationary pressures therefore lie predominately with shifting the supply schedule of the economy. If that does not prevail, demand has to be curtailed in line with supply rather than raising supply to the new demand level.

An average exchange rate weakening provides only limited economic stimulation through higher exports if monetary policy is allowed to respond accordingly. The exchange rate depreciation is neutralised and with higher inflation, a real exchange rate appreciation cannot be excluded. If an exchange rate shock is accompanied by a responding interest rate shock, a scenario that occurred in 1998, the initial impact on the economy is quite severe but given that inflationary pressures are curtailed rather soon, a medium term environment is created for lower average short term interest rates and thus higher economic activity. However, the simulations show that if the focus of monetary policy remains unaltered i.e. the reaction function remains unchanged, neither a gradual nor an initial drastic depreciation will have a sustained impact on the real economy.

The simulation results tend to support the notion that monetary policy should be as transparent as possible to ensure that policy responses are anticipated. This raises the effectiveness of monetary policy as it reduces the time period required for achieving economic balance. While the SARB has been predictable and transparent in the past, the possible introduction of inflation targeting would further enhance this objective.

### **9.3. FURTHER RESEARCH**

An important area of research has become the incorporation of learning in expectation models, as has been the case, for example, with the model of the London Business School. Learning processes are generally modelled by means of a time varying parameter model through the use of a Kalman filter (see, for



example, Allen et al. 1994:20-21 how this was accomplished in the LBS model). With a learning model, every time new information becomes available, the coefficients of the expectation process are updated. There is therefore an updating equation for the coefficients. This equation may be interpreted as an adaptive expectations model in that the new coefficient is a function of the previous coefficient and the forecasting error of the model weighted by the covariance matrix and the variance of past forecasting errors (Cuthbertson et. al. 1992:199-208).

A learning model does not assume constant parameters but the coefficients are updated to derive better expectations/forecasts. The aim is to model how the parameters vary through time. Such an approach is particular useful in a changing policy environment, where economic agents constantly learn about the new policy stance without assuming a particular time period for acquiring renewed RATEX. It also reconciles rationality with non-model consistent expectations on the basis that rationality prevails as agents continuously attempt to acquire a better understanding of the underlying structure so as to improve their forecasts. In this case, the strong RATEX assumption, that full model knowledge prevails, is not necessary for rationality or for addressing the Lucas critique. This approach would provide a more comprehensive assessment of monetary policy simulation in South Africa, particularly if the simulation assumption is one of fundamental policy change where economic agents have to learn the new reaction function through time.

The Bank of England (1999) provides an alternative methodology to learning that can be more easily incorporated into the present study. In their macroeconometric model, expectations are specified as a simple autoregressive

model, estimated using a ten-year rolling regression (Bank of England 1999:65-66). Before every forecast, the equation is re-estimated. While the equation is non-structural and the Lucas critique is therefore applicable, the re-estimation process captures an element of learning. Regularly re-estimating the structural expectation process in the current study would follow this methodology and still address the Lucas critique to the extent to which the actual reaction function is also re-estimated. This approach can become of particular relevance for policy simulations over forecast horizons where the latest information needs to be incorporated.



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